AIRCRAFT DESIGNERS' DATA BOOK

BY

LESLIE E. NEVILLE

Curtiss Wright Corp.; Formerly Editor of Aviation; Director, Standard Aeronautical Indexing System; Member, Institute of the Aeronautical Sciences

FIRST EDITION

McGRAW-HILL BOOK COMPANY, INC.

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CONTENTS

INTRODUCTION

As far back as twenty years ago the editors of the magazine *Aviation* realized the value, in aeronautical engineering, aircraft maintenance, and technical education, of the three-dimensional drawing. This method of presentation unfortunately did not originate in this country. Aviation magazines in England and France had developed the technique to a high state of perfection before we attempted it here. Geographical compactness and lower publishing costs had made it possible for foreign publishers to pioneer in this field. To produce the same or better results here would have been almost prohibitive in terms of time required, travel expense, and production cost. In addition there were few persons if any in the aviation field possessing the combined abilities of artist and engineer required for this work.

It was not without considerable courage and a firm belief that a single picture had greater information value than many thousands of words that we embarked on the project here during the false prosperity of the famous boom of 1929. Economic conditions were temporarily favorable. Against that background we had as tools a modest budget, a good deal of determination, and an ex-taxi driver with good mechanical sense and a flair for drawing. Another important asset was the ability and personality of McGraw-Hill's Bela Z. Reiter, veteran in the field of graphic presentation, whose cooperation made our task possible.

Our artist had drawn intricate mechanical parts before but was not familiar with aircraft design details. So the St. Louis Aircraft Show of 1930 was selected as his training ground, and we personally selected the details for him to sketch, pointing out the features that should be emphasized. For ten long days he sketched and sketched and sketched. After hours we studied the day's crop and returned to the show the next day to improve them and make more drawings.

The first group published were considerably better than the first of the sketches, but there was much to be desired. We blushed, but not with pride, when we compared them with the superb work of Gaudfrois and the others abroad. But we had made a start, and we continued to improve the quality of the work until depression forced us to suspend operations during the starvation years in the mid-thirties.

Even in the beginning we were handicapped by geography. An air show furnished us a diversified group of planes from all around the country. Our artist could obtain a sufficient number of sketches from such a gathering to justify travel expenses. But to flit back and forth across the continent following the advent of new designs simply was not in the cards. British and French industry was located within easy travel of London or Paris. Ours was shaped like a dumbbell with eastern and western lumps and very little in between. So we created a technique of developing sketches from photographs plus information.

A single photograph had little value, but with time and effort we were able to explain our needs to engineers in plants who learned to furnish us with pictures of small but interesting design details taken from a sufficient number of angles to enable our artist to sketch the detail faithfully.

As soon as the aircraft industry had revived sufficiently from the starvation period, we resumed the publication of this type of material in a department called *Aviation's* Sketchbook of Design Detail. Then came the war and with it new applications of the technique.

Early in the war the tabloid trend in presentation led to an outburst of graphic methods in the aviation field. One manufacturer learned that not only engineers but military procurement officers were able to grasp design features far quicker when they were presented in living three-dimensional form. Accordingly he scoured advertising agencies for illustrators with technical knowledge and set up a large graphic illustration department at his plant. Another engineer developed a method of production illustration to speed up the training of new workers by presenting their parts of the manufacturing job in sketch form.

Before all this happened we were invited by the Navy and Air Force to develop and publish a magazine to help speed aviation production by spreading the know-how among aviation workers. We adapted our technique to the quick presentation of production short cuts. In each item we supplied a sufficient number of sketches to show the reader how to make and how to use the device which saved man-hours. We also developed the "graphic sequence" type of article in which numbered sketches showed detailed operations on a motion-study basis.

Wings magazine saved many thousands of man-hours throughout the war and proved an important principle in publishing. It proved that ideas could be got across to readers accurately in much less time and with fewer words than ever before. This principle is still sound and is being recognized to a greater extent each day as competition for the reader's time increases

Our sketches in *Wings* and *Aviation's* Sketchbook were widely applauded. So we decided to make the technique useful in still other ways.

We had learned from earlier experience that design details of older aircraft frequently furnished solutions for design problems in current work. Accordingly we set up a program to publish design features of aircraft as soon as they could properly be declassified.

Out of this thinking came a series of design analyses of aircraft, engines, and certain accessory equipment which was widely acclaimed by engineers, maintenance men, and technical educators. Hundreds of requests were made for this material, and many thousands of reprints were made. In some cases supplies of both the publication and the reprint stock were exhausted as requests came in long after the articles had appeared in print.

This volume constitutes a rearrangement of the design analysis material in terms of the major components of the aircraft with the addition of selected current data on more recent aircraft. The treatment is primarily pictorial, and the arrangement follows closely the method used by many engineers and teachers who retained the magazine material for reference.

The aircraft selected for these studies are representative of many different types developed in the past few years in this country and abroad. They include landplanes and seaplanes of both metal and composite construction. For convenience they are grouped in terms of power plants—single engine, twin engine, and aircraft having four or more engines.

Chapter I. GENERAL DESIGN CHARACTERISTICS

PART 1. SINGLE-ENGINE AIRCRAFT

Republic Seabee

Structurally the Seabee represents such a reasonable departure from intricate conventional design that its radical simplicity in make-up alone, embodying more than adequate strength characteristics, recommends it as a basic pattern for future engineering of aircraft—military, transport, and personal.

The fixed and movable airfoil structures of the Seabee are essentially ribless components comprising simple spar foundations covered by stiffened skin. The hull, of almost pure monocoque design, consists of heavy-gauge shell with relatively few internal connecting members.

The Seabee project unmistakably demonstrated that design complexity is the fundamental reason for high production costs, since there are narrow limitations to the production engineer's ability to cut direct manufacturing labor charges when he is confronted with complicated subassemblies. And it has been shown that when the design is formulated, it must be predicated on attendant tooling and manufacturing problems.

In sharp contrast to the conventional aircraft structure, containing many small and interlocking component assemblies laboriously put together by hand, the simplified structure of the Seabee lends itself readily to rapid fabrication with equipment (1)* of the type generally used in the automobile industry—units such as mechanical presses, press brakes, and automatic screw machines. And, large sections of the structure were assembled on automatic gang riveting machines.

Using this type of fast-production equipment, each tool was designed for maximum output. For example, if a mechanical press was capable of 300 strokes per hour, the corresponding tool

* The numbers in parentheses refer to the illustrations.

Fig. 1. Camel-back draw die for forming skins. This is a temporary tool used until a production unit was available. It was employed with a steel mat (seen in the background) which gives sharp impressions of the beads with hydraulic press utilizing a rubber female. With the mechanical press, a steel female would obviate the need for a mat.

was designed for the same number of strokes—to produce an average of 300 parts per hour. To ensure operation of equipment at maximum speed, additional man power was assigned when necessary.

Assuming a run of 5,000 planes at a given rate, the cost for the automotive-type tooling was estimated to be about \$300 to \$350 per pound of air frame, and since the air frame weighs about 1,100 lb, the over-all cost of production tooling would be approximately \$350,000.

Installation of the new tooling, however, was predicated on a frozen airplane design—one that would be used for at least a year's production without any major changes in design.

In a study of the economies resulting from use of automotive-type tooling for the simplified, ribless structure, the distribution of stabilizer tooling and of labor and overhead costs was estimated over production runs of from 100 to 5,000 planes, and it was determined that the new tooling would pay for itself in less than 200 aircraft (2).

With the choice of automotive-type tooling, the initial problem was the selection of materials adaptable to fast production methods. After extensive investigation, 61SW was chosen for severely formed parts in which high strength was not important, and R-301W was selected for a slight advantage in formability over other high-stress materials and partly to eliminate heat-treat operations in the manufacturing process. It was estimated that heat-treat per pound of air frame added 3 to 6 cents in direct labor costs at the time.

An important feature of the Seabee production plan was a more closely controlled parts-flow time—3 days from raw material to finished product—to eliminate stock rooms and attendant personnel and paper work.

Another major consideration lay in the procurement cost of items such as instruments, electric switches, interior trim and hardware, and other equipment. In many instances, it was found that good, comparatively inexpensive automotive-type units could be used.

Briefly, the considerations leading to the simplified design of the Seabee and the underlying theory were as follows: The prototype plane was built only to prove the general design. The craft was a three-place 175-hp all-metal amphibian monoplane, using good but conventional structure throughout. It

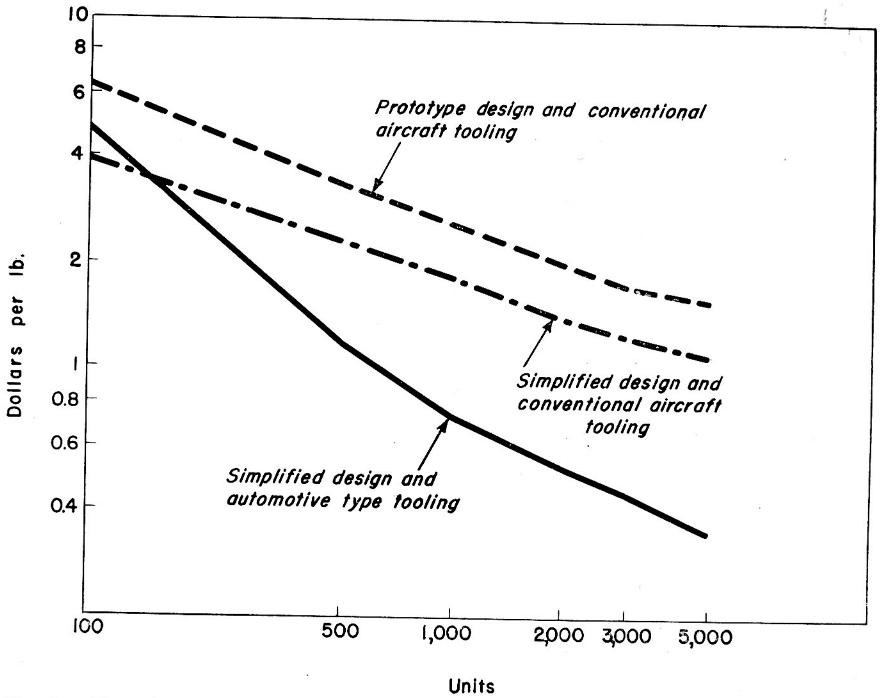

Fig. 2. Chart showing the distribution of stabilizer cost (labor, tooling, and overhead—less material) in dollars per pound with prototype design and conventional aircraft tooling, with simplified design and conventional aircraft tooling, and with simplified design and automotive-type tooling. It is to be noted that the latter tooling pays for itself in less than 200 craft.

was an outgrowth of an original design by P. H. Spencer, Republic development engineer.

Manufacturing and cost considerations prompted an investigation to determine how air-frame structures could be simplified to reduce manufacturing costs sharply. It was believed that extensive simplification could be achieved, with consequent great reduction in assembly components, while maintaining the high standards required in aircraft construction.

Assigned to redesign the Seabee air frame to meet reduced cost requirements, Alfred Z. Boyajian, structures project engineer, reviewed (*a*) the evolution of conventional design, to ascertain why this type of structure had been adopted; (*b*) production time studies, made available from wartime experience, to establish what, in general, was causing manufacturing costs to be so high; and (*c*) stress-analysis procedures to determine what conceptions existed which might be altered to justify a vastly simplified structure.

It became apparent that (*a*) despite the progression from a wood and fabric-covered wing to the all-metal unit, the latter still was fundamentally similar in basic pattern to the former; (*b*) production complications arose because of the complex "egg-box" structure with many internal interconnected members, in turn connected to the outside cover; and (*c*) the necessity for retaining numerous rib components (as "irreplaceable" internal members of the conventional all-metal wing) had not been clearly established.

When engineer Boyajian's simplified and comparatively ribless structural design was first proposed on paper, it was subjected to much discussion in large conferences of engineering personnel. The absence of conventional ribs in the design created much doubt as to structural airworthiness—a doubt voiced because it was believed that, in accordance with customary methods of stress analysis, the proposed simplified structure was considered to be probably deficient in strength requirements. It was thought, generally, that other than a rib there was no structural member deemed capable of transferring air-load shears in a chordwise direction to the bending-resistant spars.

Boyajian's theory was that, if the cover of a stressed-skin wing were sufficiently stiffened, thus creating a heavy torque box, it should be possible to transfer such air-load shears with a

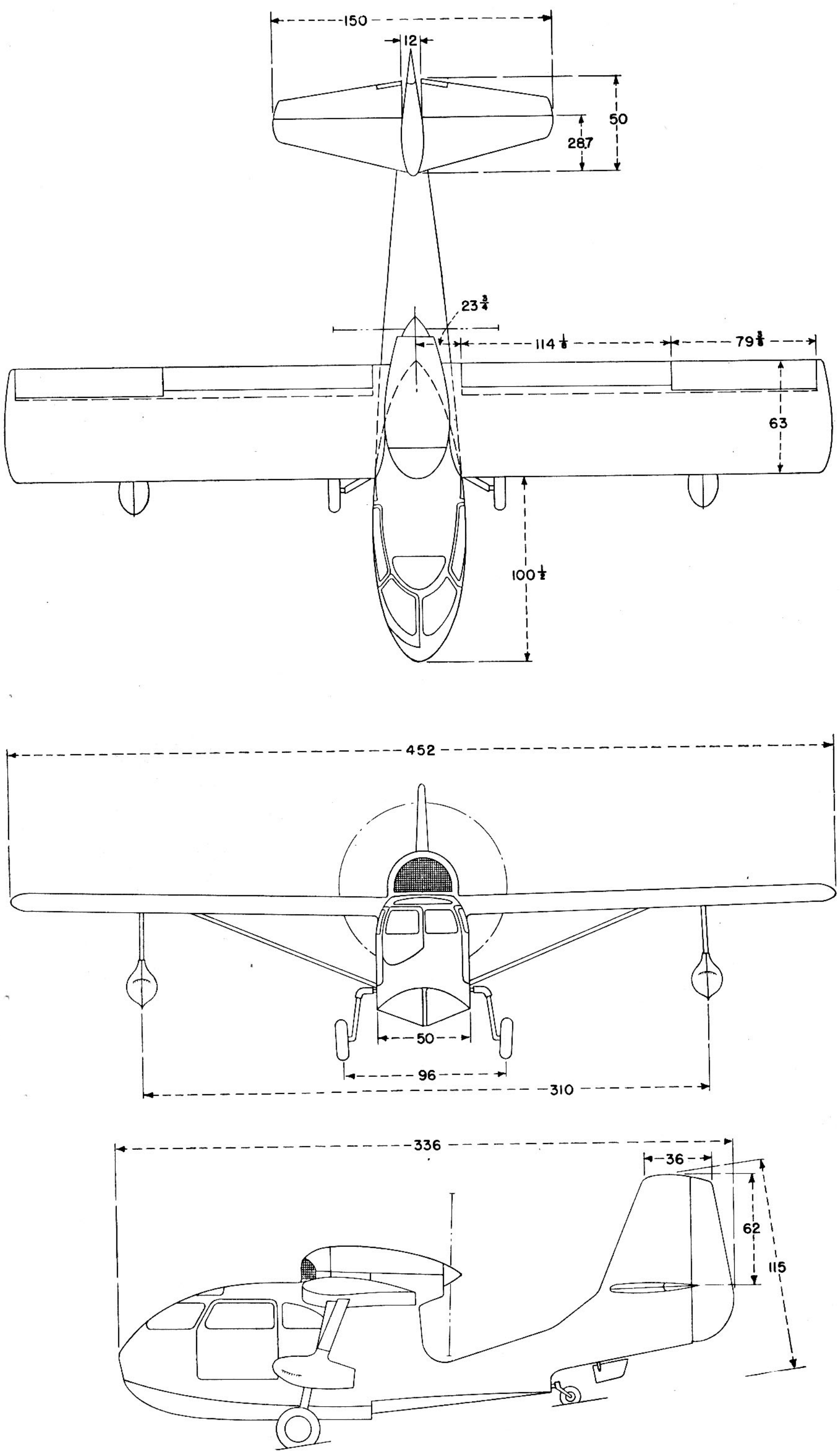

Fig. 3. Three-view aspect of Republic Seabee amphibian.

minimum of internal structure. He arrived at this conclusion after reasoning that the conventional practice for a stressed-skin wing, wherein a section is isolated and analyzed as an independent structure, was not justified, since it was assumed that the other portions of the over-all structure did not contribute any vital additional strength characteristics to the isolated section.

An isolated ribless section would, it is true, deflect under air load because of the absence of shear rigidity and would give a large torsional displacement with respect to the end ribs. But a torque box, for example, comprising the stressed-skin leading edge would offer appreciable restraint to such torsional displacement. Further, Boyajian believed that the L.E. cell and the aft cells would serve, in some degree, as beams in bending between end ribs, and that the secondary spars would also act so. He reasoned also that individual beads on the L.E. skin would serve partly as truss members pinned at the L.E. Boyajian's proposal, in effect, was a new application of the theory of stress analysis—a radical departure from conventional practice—which had to be substantiated by static test as the design proceeded, since the stress in the simplified structure could not be adequately calculated.

Of all-metal construction, the four-place Seabee is powered by a Franklin 6A8-215-B8F engine developing 215 hp at 2,500 rpm with a high speed of 120 mph; cruising speed at 75 per cent power is 103 mph, landing speed is 58 mph; and range at cruising speed is 560 miles (75 gal). Climb, first minute, is 700 fpm.

Under full-load condition, take-off from land is 800 ft; from water, 1,000 ft.

Dimensions are: span, 37 ft 8 in.; length, 28 ft; height, 9 ft 7 in.; wheel span, main gear, 8 ft; interior cabin width, 46 in.; interior cabin height, 50 in.; interior cabin length, 110 in.; baggage compartment, 20 cu ft, and draft, loaded, 18 in. (3).

Flight instruments are basic CAA and ball bank. A two-way tower and range radio is carried.

Comparative data of the conventional prototype and the simplified design are as follows:

	Prototype	*Simplified*
Passengers.......	3	4
Wing area, sq ft..	171	196
Gross weight, lb..	2,900	3,000
Weight empty, lb.	2,130	1,950
Air-frame weight, lb............	1,260	1,140
Air-frame parts...	1,800	450
Air-frame fabrication time, man-hours.........	2,500	200
Air-frame tool cost at 5,000 per yr.	$1,750,000	$350,000

North American P-51

Among single-seat, single-engine fighters, the P-51 Mustang (1) was credited in the Second World War with being the best low-altitude cooperational aircraft, most versatile dive bomber, fastest high-altitude fighter, and the plane with the longest range.

This record was achieved by a plane whose basic design (2) and most of its original specifications remained unchanged. New models incorporated equipment and design refinements but retained the desirable advantages of the preceding versions.

The original Mustang, designed and built for the British in less than 120 days, was intended for low- and medium-altitude work. It was a low-wing all-metal monoplane powered by a twelve-cylinder V-type Allison engine of 1,150 hp, and it was credited with close to 400 mph speed. RAF pilots said it was highly maneuverable and had no "cranky" characteristics; and for those early war days, it was heavily armed with .50-caliber machine guns, one on each side of the engine and one .50-caliber and two .30-caliber guns in each wing. A gun camera was mounted in the left wing.

In the AAF P-51 version, equipped with two 20-mm cannon in each wing, the P-51 acquired fame as a "train buster," retaining the high maneuverability plus somewhat increased speed. Stripped of guns and with a K-24 camera, it became a widely used reconnaissance plane.

As the A-36 Invader, still retaining the characteristics of its fighter forebear, it became a phenomenal "secret" fighter–dive bomber in the invasion of Sicily. Equipped with dive brakes and six .50-caliber guns, the Invader carried two 500-lb bombs.

The next revision retained the basic design and uses of previous models but increased speed with a 1,465-hp Allison engine with single-stage, single-speed supercharger. Auxiliary fuel tanks gave considerably more range. Armament consisted of four .50's, two in each wing and wing bomb racks.

A further revision was the installation of the Packard-built Rolls-Royce 1,500-hp Merlin engine with two-speed supercharger. Removable bomb racks, depth charges, chemical tanks, and auxiliary fuel tanks also were added. Armament was four .50-caliber guns. Speed and ceiling went up, whereupon the Mustang was officially credited with the highest ceiling ("over 40,000 ft") and the greatest speed ("over 425 mph") of the fighters then in operational existence. Since it possessed the longest range of the single-engine fighters in the war, the Mustang accompanied the heavy bombers of the Eighth Air Force on their longest missions.

These achievements are remarkable in that they were accomplished by

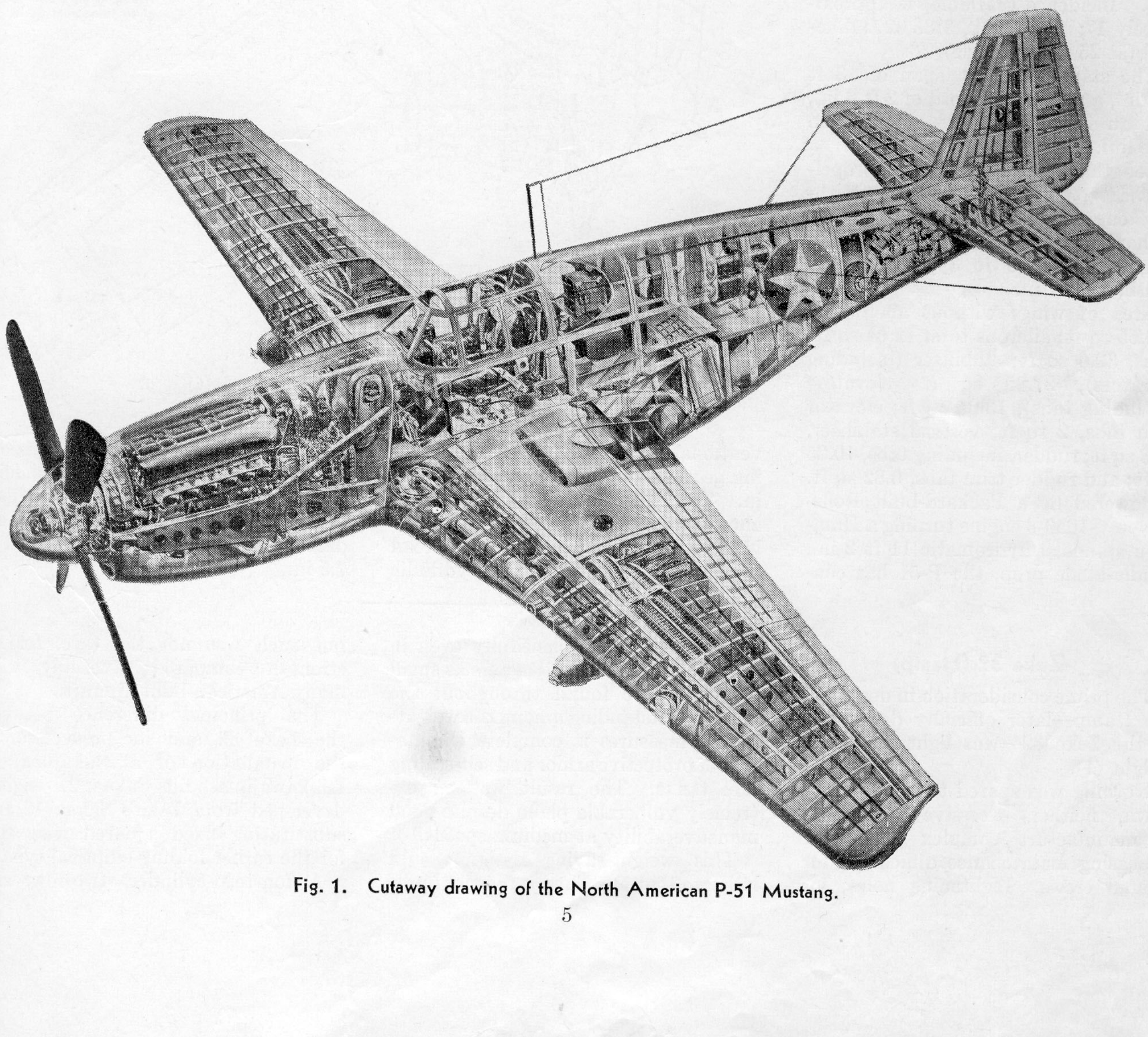

Fig. 1. Cutaway drawing of the North American P-51 Mustang.

refinements of known accepted practices rather than the employment of unknown engineering features.

Such performance is attained by close attention to aerodynamic cleanness of design, employing an efficient, low-drag, laminar flow airfoil, a modification of an NACA design. Second-degree curves, calculated as mathematical expressions, are used for external lines of fuselage, fillets, ducting, and air scoop.

The air scoop is located just below and aft of the fuselage center, where it was found to create less drag while operating efficiently. Oil and coolant radiators are in the air scoop.

Dimensions and leading particulars of the P-51 are: span, 37.03 ft; length overall, 32 ft 2⅜ in.; length (tail wheel on ground), 30 ft 8 in.; height (tail wheel on ground, propeller blade vertical at top), 12 ft 6 in.

Airfoil section is NACA low-drag type. Chord is 8 ft 8 in. at root and 4 ft 2 in., 215 in. from fuselage center line. Incidence (variable) is approximately 1°; sweepback, 3°35′32″; dihedral (at 25 per cent line), 5°.

The stabilizer has a span of 13 ft 2⅛ in., a maximum chord of 2 ft 6 in., and an incidence of 2°. It has no dihedral.

Length of fuselage from tip of propeller shaft to tip of tail is 30 ft 9 in.; without engine mount (front of heat exchanger to tip of tail), 24 ft 2½ in.; height (max.), 6 ft 3⁷⁄₁₆ in.; max. width, 2 ft 11 in.

Area of wings without ailerons is 220.55 sq ft; ailerons total 12.64 sq ft; flaps, 32.6 sq ft; stabilizer (including elevators), 27.85 sq ft; elevators (including tabs), 13.05 sq ft; elevator trim tabs, 2 sq ft; vertical stabilizer, 8.83 sq ft; rudder, including tabs, 10.25 sq ft; and rudder trim tabs, 0.82 sq ft.

Powered by a Packard-built Rolls-Royce V-1650-3 engine turning a Hamilton standard hydromatic 11 ft 2 in., paddle-blade prop, the P-51 has conventional, hydraulic, retractable landing gear. Main gear tread is 11 ft 10 in. The wheels are of magnesium-alloy construction with diameter of 27 in. and with 27-in. all weather tread tires. The brakes are disk, hydraulic type; shock struts, air-oil combination.

The tail wheel is the hydraulic retractable, steerable type with air-oil combination shock strut and wheel diameter 12.5 by 4.5 in. Oleo travel is 7.5 in.

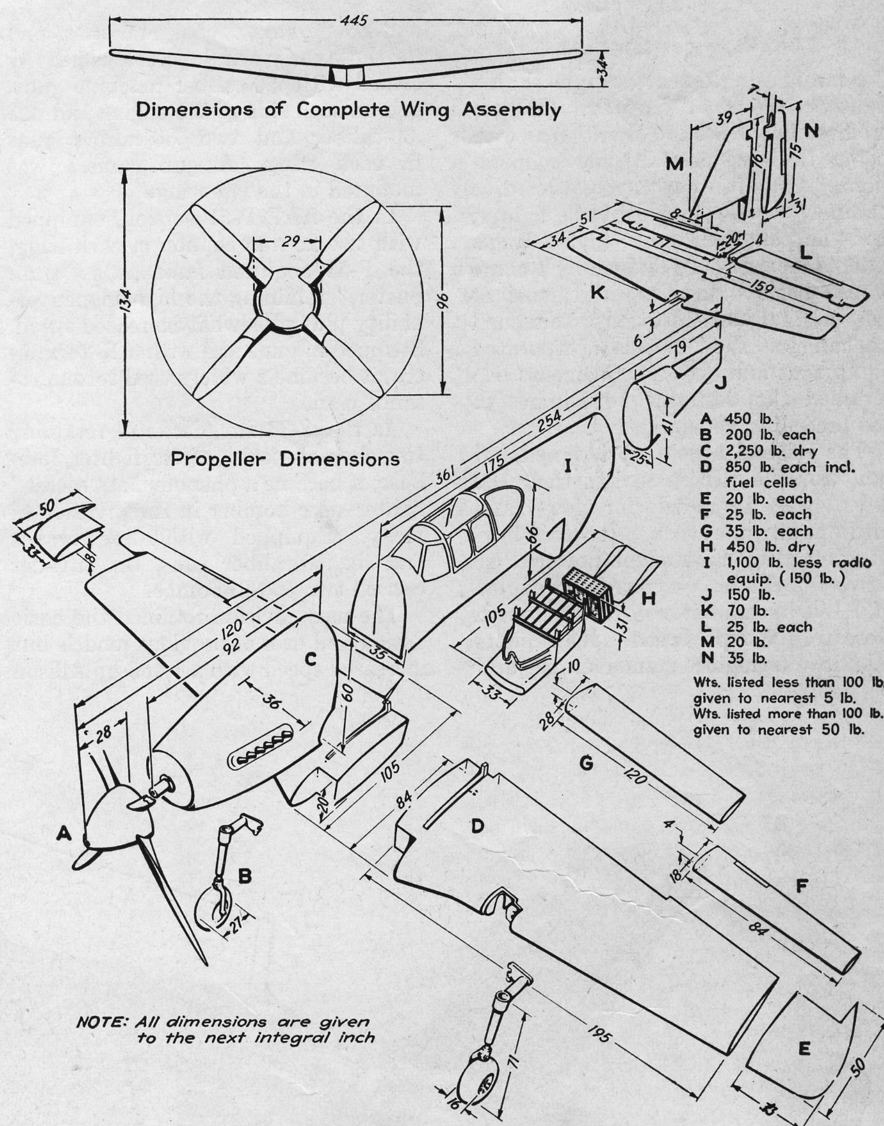

Fig. 2. Tabulated weights of principal assemblies.

Zeke 32 (Hamp)

The prime consideration in designing the Hamp—later officially designated as the Zeke 32—was light structural weight (1).

Nothing was spared to keep weight down, neither excessive man-hours to manufacture complex units, nor increasing maintenance difficulties for ground crews. Lightening holes, for example, are used plentifully even in the pilot's seat, and diameters as small as ½ in. are found throughout the craft. Outstanding among the weight-saving measures is complete elimination of protective armor and self-sealing fuel tanks. The result was an extremely vulnerable plane despite good maneuverability at medium speeds.

This weight-saving design would indicate that the plane is flimsily built, but such was not the case, for its strength compared favorably with many American-built aircraft.

The principal difference between the Zeke 32 and its predecessor is the installation of a Nakajima, or Ishikawajima-built Sakae 21 engine, developed from Zeke's Sakae 12 and substituting fixed squared wing tips for the earlier folding elliptical type.

A fourteen-cylinder, two-row, air-

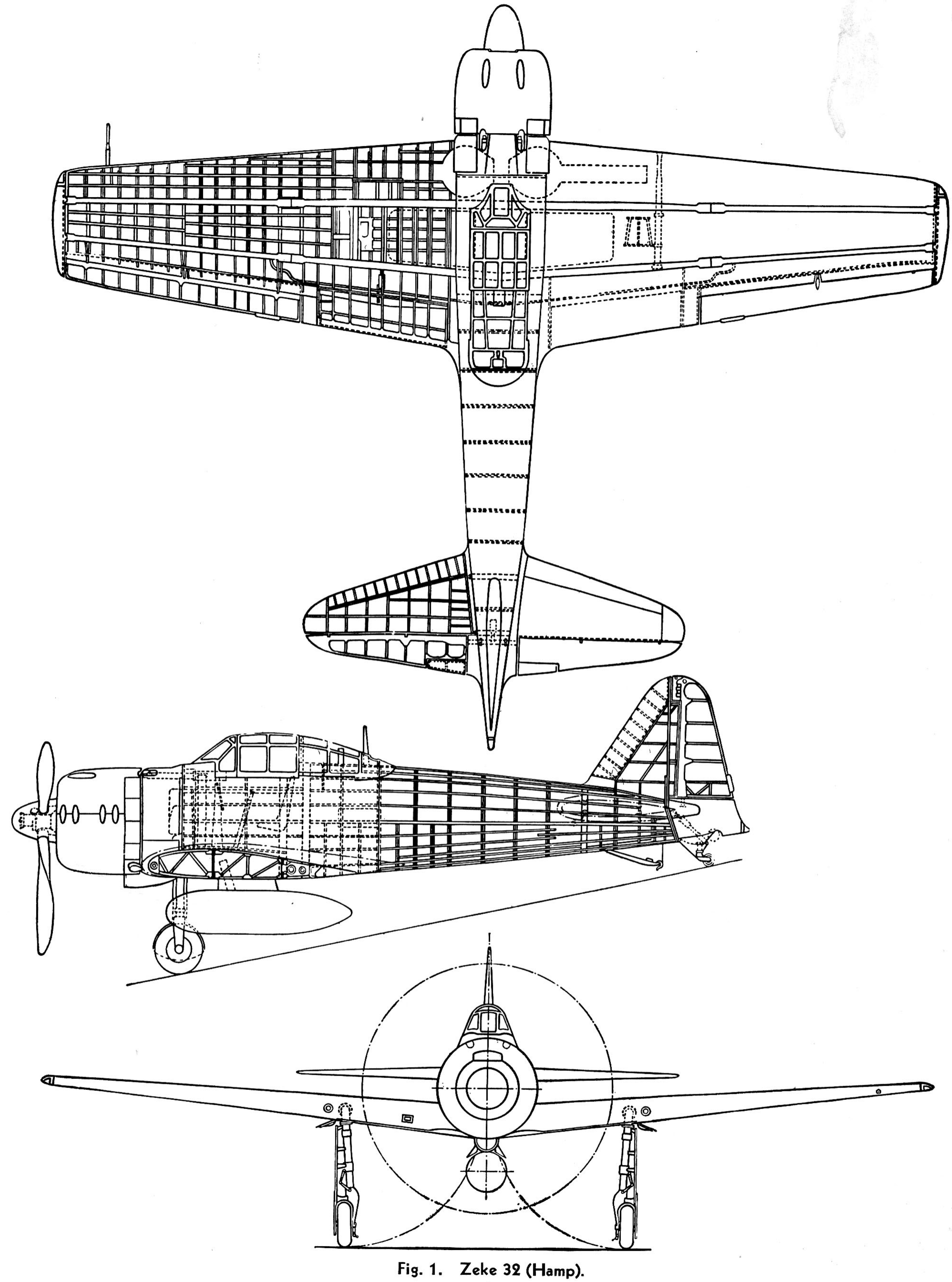

Fig. 1. Zeke 32 (Hamp).

cooled engine, the Sakae 21, develops 1,020 hp at 2,600 rpm at 6,400 ft, turning a 10-ft constant-speed propeller 15 in. in diameter, which is very similar to Hamilton standard design. As installed in Zeke 32 the engine had a downdraft carburetor and a two-speed blower in place of the older single-speed. The installation necessitated moving the fire wall aft 8 in. and changing the cowling to put the air intake at the top.

Specifications and Design Data

Span	36 ft 2¼ in.
Length	29 ft 9 in.
Height	9 ft 2 in.
Gross weight:	
Max. load	6,331 lb
Normal load	5,155 lb
Weight, empty	3,913 lb
Wing area	232 sq ft
C.g	31% M.A.C. (approx.) 0.075 in. forward of main spar
Airfoil:	
Root	NACA 2315
Tip	NACA 3309
Max. chord thickness:	
Center line	8¼ in.
Tip	4⅛ in.
Chord:	
Center line	8 ft 3 in.
Fuselage side (20 in. from center line)	8 ft 1 in.
Tip	4 ft 1¼ in.
Mean chord	6 ft 4.8 in.
Aspect ratio	5.5
Dihedral, on 30% chord	6.5°
Taper ratio	.44
Wing loading	21.3 lb/sq ft
Power loading	5.42 lb/hp/sq ft
Aileron area, total	20.2 sq ft
Aileron span, each	9 ft 7⅝ in.
Flap area, total	16.44 sq ft
Flap span, each	5 ft 3¾ in.
Horizontal tail area, total	51.68 sq ft
Stabilizer area, total	40.84
Airfoil:	
Root	NACA-.0009-64 (approx.)
Tip	NACA-.0010
Span	15 ft 5 in.
Mean chord	3 ft
Aspect ratio	5.7
Taper ratio	.439
Elevator area, total	10.85 sq ft
Percent balance	11.35
Trim tab area	1.19 sq ft
Fin area	7.92 sq ft
Rudder height	4 ft 6 in.
Rudder area	7.7 sq ft
Rudder area, forward hinge line	0.7 sq ft
Rudder trim tab area	0.065 sq ft
Percent balance	9.64

Performance

High speed	350 mph at 17,000 ft
Stalling speed:	
Power off, wheels and flaps up	85 mph
Power on, wheels down, flaps down 40°	65 mph
Power off, wheels down, flaps down 40°	78 mph

Having an OD of only 45 in., the redesigned cowling was an improvement, for it was cleaner and fitted more snugly. Built in upper and lower halves, it was carried on channel section rings supported by steel links on front and rear rocker boxes. The two halves were joined by hook-type clamps, and handholes for access to the clamps were covered by fairing plates held in place by quick fasteners.

Generally of sound design, the engine accessories were, however, not so sturdy as the American units whose design they follow. They were cooled by a scoop inside the cowling which brought air over the top of the cylinders, with several small ducts forcing air directly on some of the units.

Fleetwings BT-12

Three main objectives dominated all decisions in designing the BT-12: (*a*) a trainer which would retain all desirable characteristics achieved in previous models of the type, but overcome their observed weaknesses; (*b*) a plane which would embody the utmost simplicity of maintenance; and (*c*) a direct comparison on a standard production type of the familiar dural with a material little used throughout an entire airplane—stainless steel.

To design a basic trainer is no commonplace job. The aircraft must be moderately fast and capable as a performer to serve as an intermediate step in pilot training. With two cockpits, the plane must behave consistently with either one or both occupied. It must be inherently safe, yet still be suitable for certain maneuvers as a part of training. In other words, a basic trainer is expected to do all that a bad airplane will do when improperly handled, but do it safely.

Basic Design Information

Length	29 ft 1.94 in.
Height	11 ft 9 in.
Span	40 ft 4 in.
Max. fuselage:	
Depth	76 in.
Width	49 in.
Thickness:	
Root chord	13.92 in.
Tip chord	3.48 in.
Wing area, gross	240.42 sq ft
Aspect ratio	6.67
Design gross weight	4,691 lb
Power loading	10.42
Wing loading	19.50
Ultimate load factor	8.5

The engine was brought back as close as space permits to the cockpit enclosure (1, 2) and the sweepback was greatly reduced, giving a much shorter range of shift in c.g. locations. Contributing to this was the incorporation of an integral fuel tank in the wing center section directly under the fuselage. The shift in c.g. position caused by a full or empty tank is negligible. Shortening the fore section also greatly improved pilot visibility.

The fuselage was somewhat enlarged for better streamlining, the tail section slightly lengthened, tail surfaces enlarged, and the fin set farther forward. Considerable "washout" was built into the wing (from plus 1.5° at root to minus 2°23′ at root of tip) to eliminate tip stall. As a result, the stalling speed of the plane was rather indefinite, depending on what is considered a stall. Stall warnings occurred from 88 mph on down, with actual stall from 70 to 60 mph, but the wing tips never stalled out.

Although the original XBT-12 was designed for retractable landing gear, the classification of BT's and AT's was separated at that time, and the design had to conform with fixed gear. Even though the model under study was without fairing on the landing gear, it was exceptionally fast for its type. The XBT had a top speed of 177 mph with fairing, and the later model attained 168 mph without fairing and cruised at 145 to 150, which is about the same as the AT class.

Extremely maneuverable, it yet re-

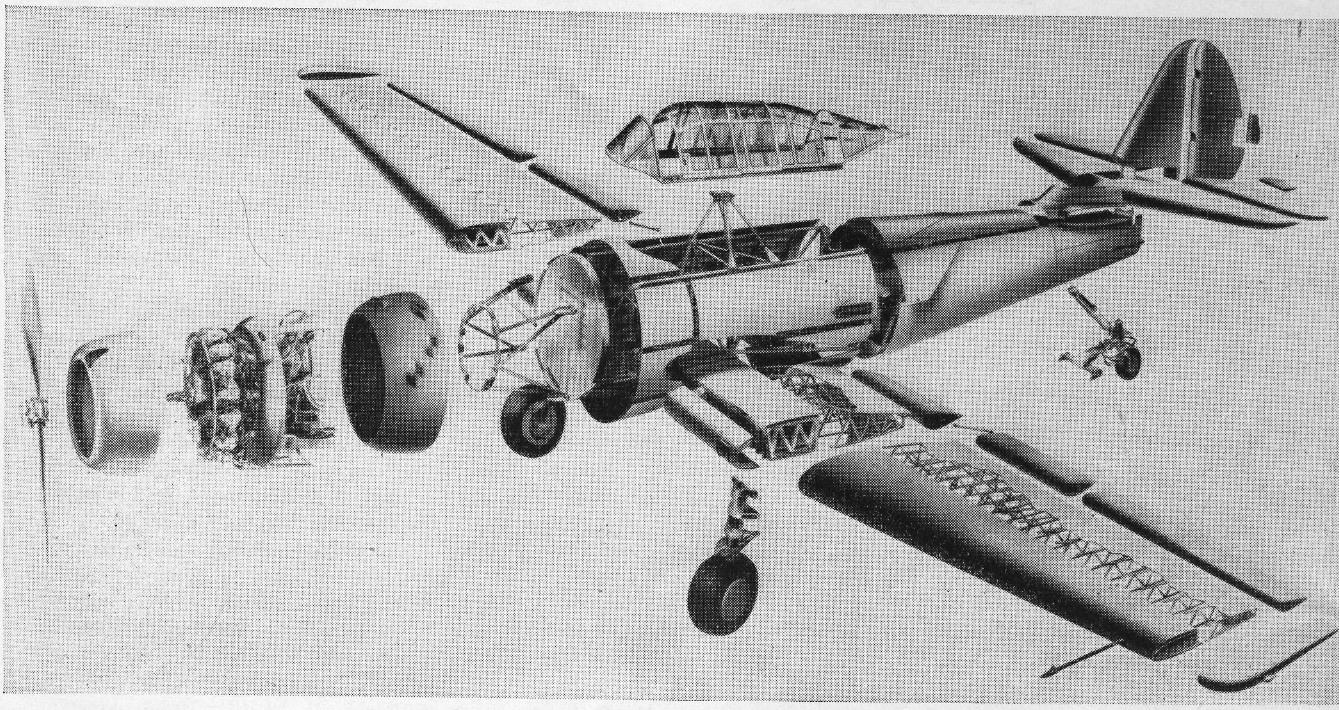

Fig. 1. Exploded parts view of Fleetwings BT-12 showing major components.

quired the proper degree of precision from the student pilot to execute a maneuver perfectly. Control forces intentionally were made moderately heavy, to simulate larger plane characteristics to which the student was progressing. Spin characteristics were good and conformed exactly to the NACA reports on what the design should do. The plane recovered in the required limits with the rudder alone, or with the stick and rudder. It would recover with controls neutral, given a little more space, and the length of time it was kept in a spin did not diminish the ease of recovery.

Ease of maintenance, because of the hard usage which is the lot of trainers and, equally, the large numbers in which they are used, was set forth by the AAF as an essential requirement; therefore, every effort was made to make the BT-12 easy to care for.

Most extensive provisions for ease of access were the removable fairing panels which cover most of the fuselage. Beginning at the nose of the plane, the ring cowl is divided into four sections held in place by four joint strips, fastened by Shakeproof fasteners. Aft of the engine section, all fuselage side panels are removable and also held in place by Shakeproof fasteners. The entire plane can be stripped of removable panels from engine to tail by one man in less than ½ hr, giving quick access to frame, controls, and wiring.

Center wing section leading edge also is removable for quick inspection of landing gear attachment and fore part of integral fuel tank. Attachment is by means of Phillips screws, as are also the plywood wing tips to outer panels.

In line with this policy is the use of bolts wherever quick detachment is desired, and the diversity of sizes has been kept as close as possible, between AN3's and AN10's. Among the points where bolt attachments are used are the following: landing gear struts are fastened by four bolts each, fuselage to the center section by six, fuselage monocoque to the tube frame by four at each joint, stabilizer spar to the fuselage by four, and fin to the tail section by four.

Another important application is in the attachment of trailing rib sections to wing spars, where ribs are fastened top and bottom by small bolts. This means that only simple tools are required for replacement of these sections in the field.

Another easily removed and replaced unit, the cockpit canopy, consists of 53ST Hunter Sash extruded-aluminum frame, welded together with gussets. The front windshield panel is a separately removable unit fastened by screws at the top and lower front of the frame at the cowl. The lower corners are fastened to brackets on the longerons by bolts. The remainder of the canopy is composed of two sliding sections over the cockpits, fixed center and rear sections. Each sliding unit can be removed by taking off the fairing around the lower part of the enclosure, aligning the rollers on the track with access holes in the frame, and removing the roller bolts. The entire canopy can be removed by taking off all fairing and unfastening the whole track from the fuselage.

All the transparent panels are set in extruded-rubber moldings and can be removed and replaced by hand. Windshield side and center panels are $\frac{3}{16}$-in. laminated safety glass; all others are $\frac{3}{32}$-in. plastic. Emergency exit is provided by means of "knock-out" panels, front and rear at the right side. Movable sections can be fixed at three positions between open and closed.

Circuit breakers in the electrical system have been concentrated in the main junction box located on the left side of the fuselage just above the L.E. of the center wing section. This unit is easily reached from the ground merely by removing the panel and cover. The use of conduit plugs wherever possible, instead of solder connections, has made installation or

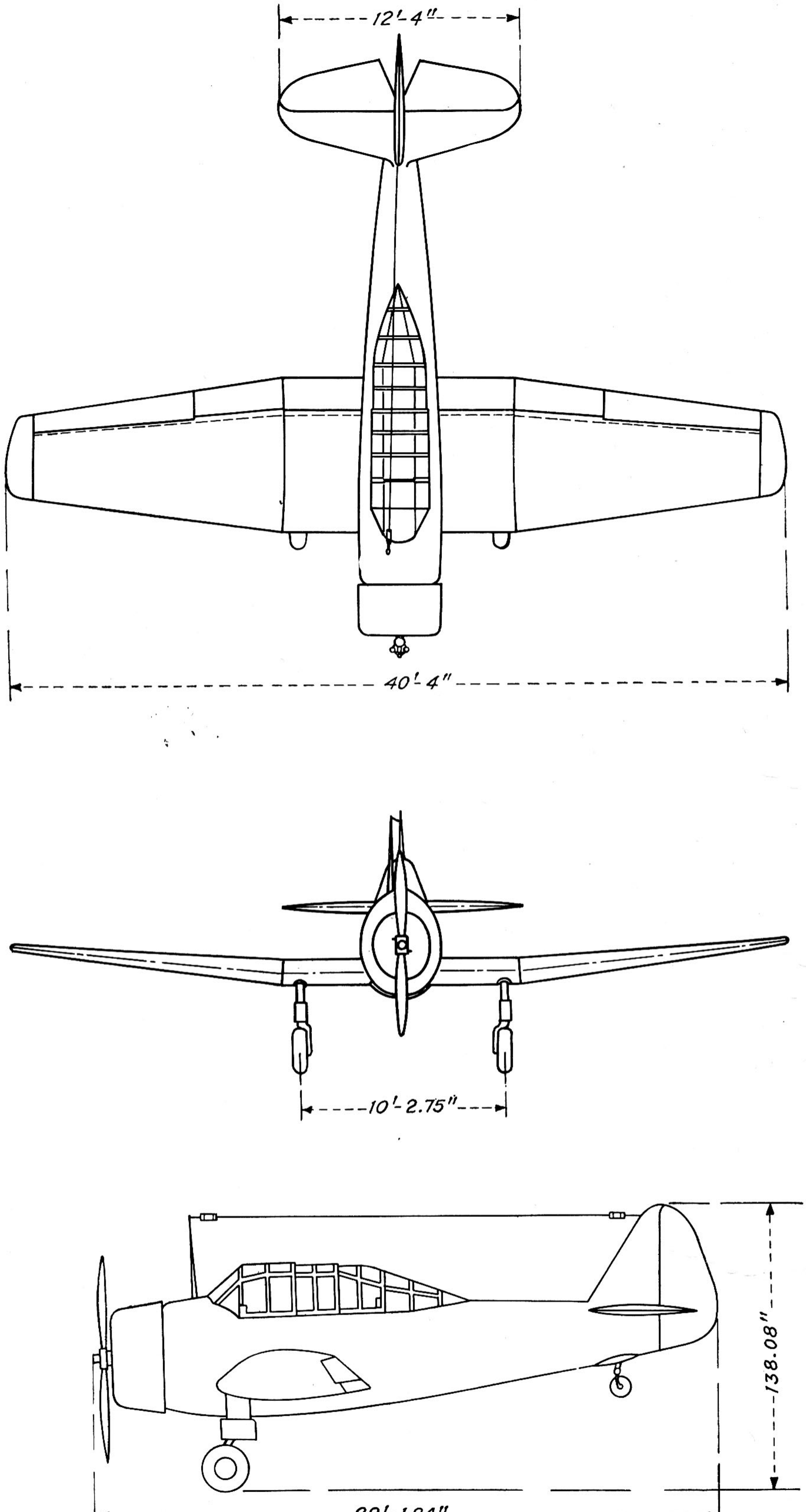

Fig. 2. Fleetwings BT-12.

removal of individual units very simple and fast.

The tool compartment also is quickly accessible from the outside by means of a hinged panel on the plywood fuselage fairing on the left side behind the rear cockpit. It is opened by the same key which operates the canopy locks. A fire extinguisher is also at hand, accessible from both inside and outside, since it is mounted on a spring-loaded door in the rear cockpit.

All control cable pulleys are packed and self-lubricating and require no attention after installation. Elevators, being of symmetrical airfoil section, have been made interchangeable. This requires a high degree of accuracy in locating and boring holes for the control attachments, but it halves replacement stocks.

Engine changing and its preparation are made easy by adherence to simplified standardized engine connections and attachment of engine to mount and mount to fuselage by bolts.

The third design objective—particularly of stainless-steel construction and a comparison standard with the same type in dural—leads to the heart of the BT-12 design, for maintenance considerations are inseparably bound up with production methods, and the material used contributes greatly to the trouble-free qualities of the plane.

Some comparisons between stainless steel and dural generally will be profitable before considering each section in detail. In stainless steel, .018 gauge is about equivalent to 24ST (.040 gauge), and steel spot welds are stronger than ⅛ rivets in 24ST. In the matter of costs, 24ST comes to about one-half that of stainless per pound. Yet such savings can be realized in stainless-steel manufacture, particularly by the elimination of riveting and finishes for detail parts and assemblies, that costs of finished articles delivered are generally lower on a production basis than in dural. This is based on experience with the BT-12, and with tail and control surfaces built for other planes.

Particularly interesting discoveries were made in connection with the fuselage mid-section. Where the XBT was constructed wholly of rectangular welded stainless truss framework, the BT-12 had a chrome-moly tubular frame, and although the latter is as much as 75 per cent cheaper in first cost, installation costs in this section were boosted to 300 to 400 per cent. In addition, it was 18 lb heavier than the stainless frame.

From a purely mechanical standpoint, a tubular framework offers the greatest difficulty to any sort of attachment, in direct contrast to straight-sided members. Further obstacles are encountered in manufacture, where welding distortion with chrome-moly tubing, even with arc welding, renders a high degree of accuracy far more difficult and expensive to attain than with stainless steel.

An interesting phenomenon in connection with welding chrome-moly is its effect on a magnetic compass, for chrome-moly is inherently magnetic. The use of arc welding, almost dictated by demands of accuracy and production time, further increases the characteristic. Add to this the effects of Magnaflux for inspection—even with every attempt at demagnetization—and the result is a 30- to 40-deg compass error, and, in some cases, a completely "frozen" compass. The only recourse is to mount a remote-reading compass in another part of the plane, as was necessary in the BT-12 and many others. Since stainless steel (grade used here was 18 and 8) is austenitic and almost wholly nonmagnetic, it allows perfect accuracy of compass within the frame.

Weight empty of the BT-12 was 3,481 lb; gross weight, 4,691 lb; useful load (including crew, 400; fuel, 720; oil, 90 lb), 1,210 lb.

Weights of the wing group were: center section, structure, 336.23 lb; provisions for equipment, 13.55; outer panel, structure, 292.09; provisions for equipment, 2.42; wing tips, 9.62; ailerons (counterweight 8.4), 28.54; flaps, 43.33; gap strips, nuts, bolts, 11.97. Total weight of wing group, 737.75 lb.

Tail group weights were: stabilizer, 53.0 lb; elevator (counterweight, 8.36), 31.23; fin structure, 21.36; provisions for equipment, 1.31; rudder (counterweight, 2.10), 19.53; provisions for equipment, 1.60 lb. Total weight, 128.03 lb.

Fuselage less engine was 503.92 lb, and provisions for equipment, 9.92 lb. Total weight of the body group was 512.92 lb.

Main landing gear weight was 341.81 lb; tail gear, 45.02 lb. Total weight, 386.83 lb.

Nacelle group was 92.41 lb; power-plant group, 1,047.21; and fixed equipment, 576.05 lb.

The wing group, with gross area of 240.42 sq ft, was 3.07 lb per sq ft, and the tail group—gross area, 63.0 sq ft—was 2.03 lb per sq ft.

The limit maneuver load factors of the BT-12 were: positive, 5.67, and negative, 2.33; limit gust load factor, design gross weight, positive, 4.28, negative, 2.71; minimum flying weight, negative, 3.34; limit landing load factor, wheels, 4; limit diving speed, 250 mph.

Airfoil root section was NACA 23016; tip, NACA 4408. Root chord, 7 ft 3 in.; tip chord, 3 ft 8.22 in.; taper ratio, 2:1; angle of incidence at root, 1.5; angle of incidence at tip, −2 deg.

Dihedral, measured on top face of the front beam, was 5 deg; sweepback, L.E., 7 deg. Maximum rib spacing was 12 in. Aileron location (distance from plane of symmetry to centroid of aileron area) was 14 ft 7 in.

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Bell P-39 Airacobra

In designing the Airacobra (1), in the words of Larry Bell, "We went back to fundamentals." These were fire power, good pilot visibility, and good landing and ground handling characteristics. Furthermore, these engineering objectives were to be over and above ordinary fighter characteristics such as speed, maneuverability, and pilot protection built into the P-39 as a matter of "basic" fundamentals.

FUNDAMENTAL DESIGN INFORMATION

Over-all length (max.)	30 ft 2 in.
Height (max.)	9 ft 3¼ in.
Span	34 ft
Thickness:	
Root chord	14.75 in.
Tip chord	4.5 in.
Wing area (net)	197.7 sq ft
Taper ratio (root chord/tip chord)	1.97:1
Length:	
Root chord	98.6 in.
Tip chord	50.0 in.
Fuselage:	
Depth (max.)	70.66 in.
Width	34.75 in.
Load factor—ultimate	12
Design gross weight	7,496 lb

By locating the engine behind the pilot and transmitting its power through a drive shaft to a propeller gearbox in the nose, the "over and beyond" fundamentals were achieved in a single stroke. A 37-mm cannon installation and two .50-caliber machine guns in the nose plus multiple wing gun installations provided the fighter with fire power to spare. With the engine behind and below his level, the pilot can see in all directions with a minimum of obstruction.

The answer to safe high-speed landings and improved ground handling characteristics was found in the tricycle gear, now a standard feature of nearly all military and commercial planes.

DESIGN WEIGHTS, POUNDS

Wing group:	
Center section	176.9
Outer panel	675.7
Wing tips	20.2
Ailerons (counterbalance weight, 15.7 lb)	36.0
Flaps	26.0
Total wing group	934.6
Tail group:	
Stabilizer	46.0
Elevators (counterbalance weight, 12.1 lb)	33.0
Fin	14.3
Rudder (counterbalance weight, 10.1 lb)	22.7
Total tail group	116.0
Body group:	
Fuselage (less engine)	438.7
Enclosures and doors	88.1
Cowling and fillets	91.5
Total body group	618.3
Landing gear:	
Main gear	391.5
Nose wheel	125.1
Total landing gear	516.6
Power plant:	
Engine (including gearbox and extension shaft)	1,408.5
Accessories	115.6
Power-plant controls	30.3
Propeller and spinner	398.0
Starting system	43.6
Cooling system (radiator and shutters, 150.0 lb; liquid, 149 lb; expansion tank, 17 lb)	322.0
Lubricating system (tanks and supports, 13 lb; piping, ducts, and shutters, 43.2 lb)	56.2
Fuel system (tanks and protection, 240 lb; piping, 49.2 lb)	289.2
Total power plant	2,663.4
Fixed equipment:	
Instruments	60.3
Surface controls	108.0
Electrical	225.2
Communicating	62.0
Armament provisions	177.2
Furnishings	41.6
Total fixed equipment	674.3
Total weight empty	5,523.2

Useful Load, Pounds

Crew	160.0
Fuel tank (104 gal)	624.0
Oil tank (7.4 gal)	55.5
Oil for reduction gearbox (2 gal)	15.0
Machine-gun installation (.50 caliber)	161.0
Ammunition (400 rounds, .50 caliber)	129.0
Machine-gun installation (.30 caliber)	92.8
Ammunition (1,200 rounds, .30 caliber)	78.0
37-mm cannon	238.4
37-mm ammunition (30 rounds)	60.0
Gun sights	4.4
Armor plate	202.5
Armor glass	59.7
Total useful load	1,880.3
Total airplane weight with useful load	7,403.5

Unit Weight

Wing group (213.2 sq ft)	4.38 lb/sq ft
Tail group (60.2 sq ft)	1.93 lb/sq ft
Weight cooling system per normal hp (1,150 hp)	0.28 lb/hp
Weight lubricating system per gal of oil (13.8 gal)	4.07 lb/gal
Weight fuel system per gal (120 gal)	2.41 lb/gal
Limit flight-load factors:	
Limit maneuver load factors	pos. 8.0; neg. 4.0
Limit gust load factors,	
Design gross weight	pos. 5.15; neg. 4 44
Minimum flying weight	pos. 5.44; neg. 4.44
Flaps down	pos. 2.01; neg. 1.01
Limit landing factors:	
Gross weight, 7,585 lb	4.67 g
Limit diving speed	170 of calibrated speed

The airfoil root is NACA 0015, tip NACA 23009; root chord (22 in. outboard of airplane center line), 98.6 in.; tip chord (204 in. outboard of center line), 50.0 in.; taper ratio, 1.97:1; angle of incidence, plus 2° dihedral at 30 per cent upper ordinate is 4°; sweepback (leading edge), 4° 35′; maximum rib spacing, 16 in.

Spar locations are: front spar, at root chord, 11 in. approximately aft of L.E. root chord; at tip chord, 25 in. approximately aft of L.E. root chord; rear spar, 40 in. approximately aft of L.E. root chord and normal plane of symmetry.

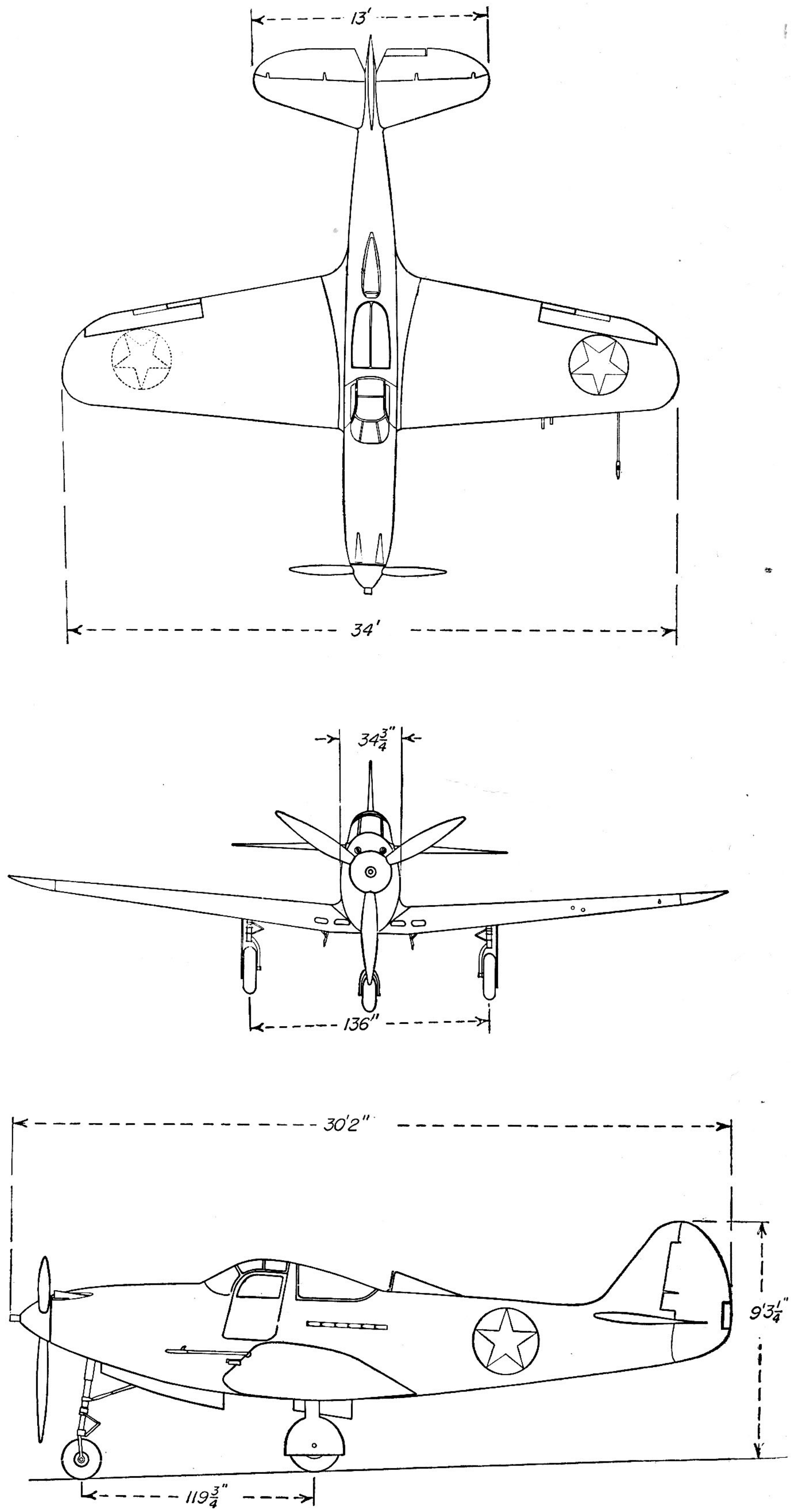


Fig. 1. Bell P-39 Airacobra.

Aspect ratio is 5.42; M.A.C., length, 80.64 in.; location, 5.41 in. aft of L.E. root chord, and 6.62 in. above L.E. root chord.

The two ailerons have an area totaling 15.46 sq ft. Location of aileron is 150.18 in. from line of symmetry of centroid of aileron area. Static balance is approximately 100 per cent. Trim tab chord is 3 in.; span, $22\frac{11}{16}$ in.; area of each tab, 0.47 sq ft.

Curtiss SB2C

The Curtiss Helldiver (1) two-seat dive bomber SB2C was built in several different versions not only in this country but in Canada by the Canadian Car & Foundry, Ltd., and Fairchild Aircraft, Ltd., during the war. This machine was also modified with float landing gear.

The power plant is the Wright R-2600-20 fourteen-cylinder, radial, air-cooled, geared, and supercharged engine. The propeller is the four-blade Curtiss electric constant-speed type.

The full cantilever wings may be folded for compactness in operation from aircraft carriers.

Wing span is 49 ft 9 in.; length, 35 ft 8 in.; height, 16 ft 11 in.: wing area, 422 sq ft.

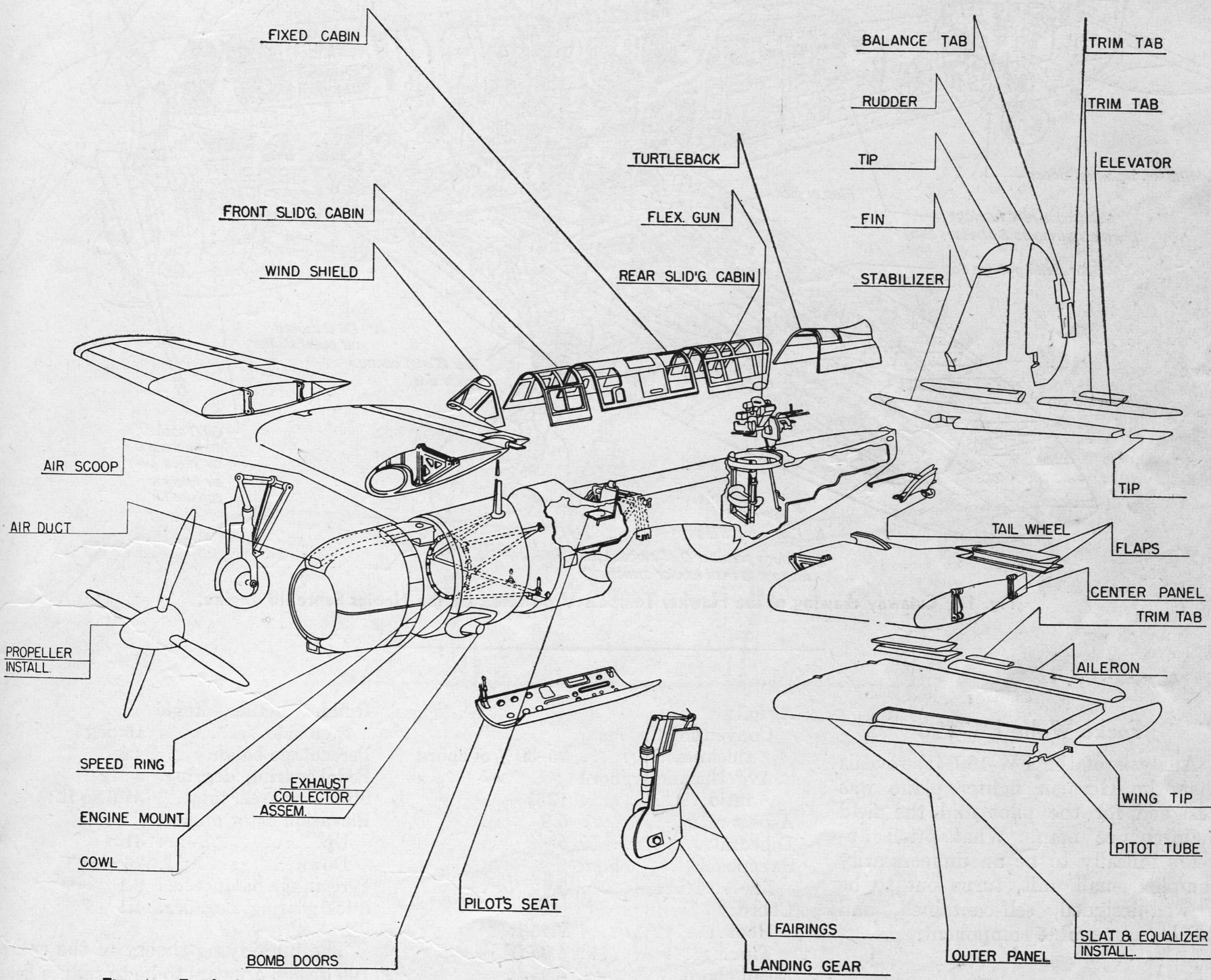


Fig. 1. Exploded view of Curtiss SB2C Helldiver carrier-borne dive and torpedo bomber, showing major assemblies.

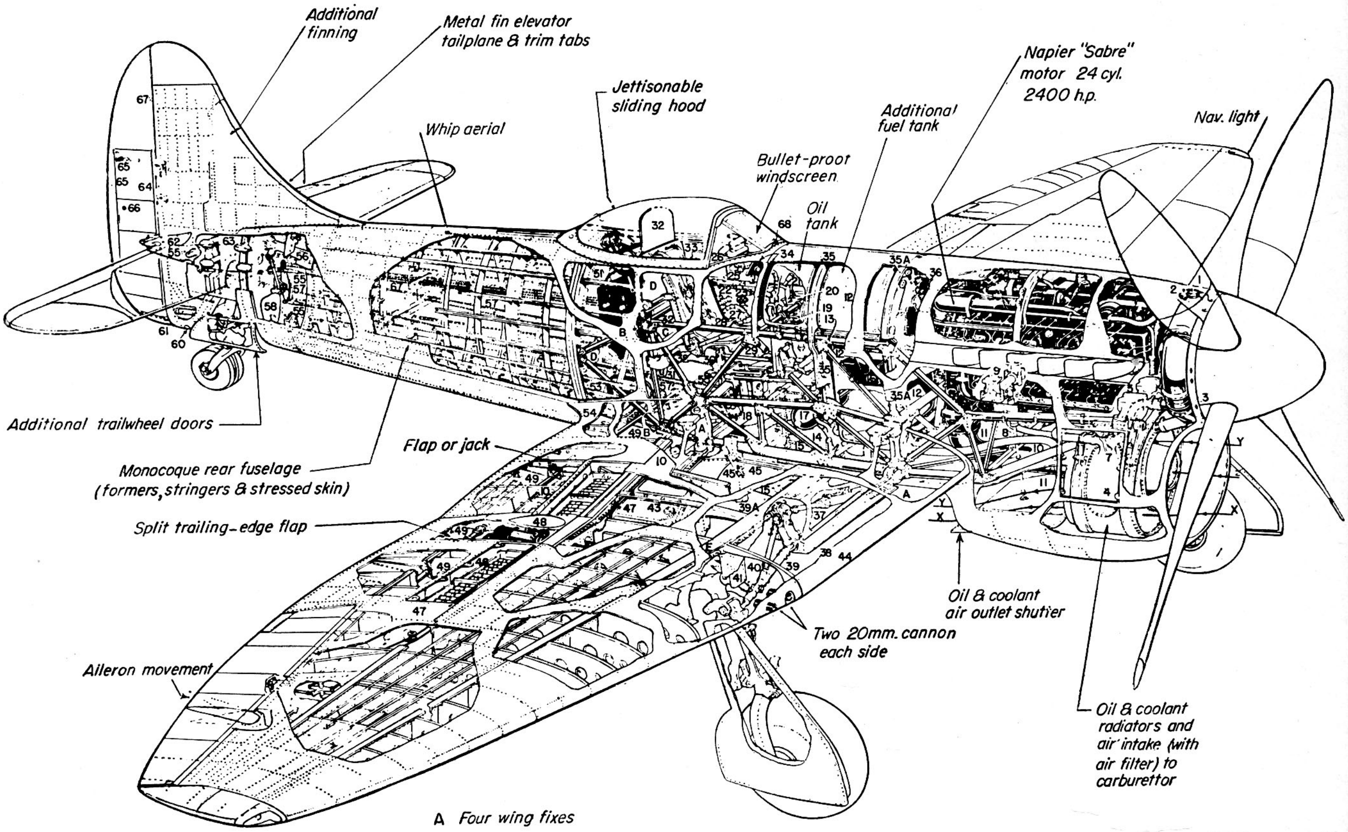
Hawker Tempest V

An outgrowth of the Typhoon series, the Hawker Tempest V (1) was the first of its design to go into production. It went into action in 1944. The Tempest V is a single-seat fighter and fighter-bomber powered by the 2,400-hp Napier Sabre IIB, 24-cylinder H-type liquid-cooled sleeve-valve engine.

Span of the Tempest V is 41 ft; length, 33 ft 8 in.; height, 16 ft 1 in. and wing area, 302 sq ft. As a fighter the gross weight is 11,400 lb. The fighter-bomber version weighs 12,500 lb with two 500-lb bombs and 13,500 lb with

two 1,000-lb bombs. Maximum speed is approximately 435 mph.

Armament consists of four 20-mm British Hispano cannon within the wings and firing outside of the propeller disk. As alternate fire power for the bombs, eight rocket projectiles may be carried under the wings.



A Four wing fixes

B Fixings (member D of monocoque fuselage to front tubular structure)

Fig. 1. Cutaway drawing of the Hawker Tempest V powered by the Napier Sabre IIB engine.

Focke Wulfe FW-190

Analysis of the FW-190 (1) reveals that the German fighter plane was designed for the pilot and the field maintenance man. What often appears initially to be an unnecessarily complex small unit, turns out to be a well-designed, self-contained, and quickly removable component.

Specifications and Design Data

Span	34 ft 6 in.
Length	29 ft 1 in.
Height	12 ft
Gross wt:	
Normal load	8,600 lb
Max. load	10,350 lb
Weight, empty	7,500 lb
Wing area	203 sq ft
Airfoil:	
Conventional, max. thickness	25–30% of chord
Avg. thickness/chord ratio	12%
Aspect ratio	5.8
Dihedral	5°
Sweepback, ¼ chord line	5.5°
Chord:	
Root	7.45 ft
Tip	4.05 ft
Mean chord	5.95 ft
Wing loading	41.7 lb/sq ft
Power loading	5.36 lb/bhp
Aileron area, total	20.1 sq ft
Percentage balance	28.8
Angles of movement	±17°
Stick gearing, deg/in.	3.2
Flaps, type	Split
Max. angle	60°
Fin and rudder area	24.3 sq ft
Rudder action, angle each side	16 deg
Percentage balance	4.6
Pedal gearing, deg/in.	6
Stabilizer area, total	31.6 sq ft
Elevation actor angle:	
Up	31°
Down	26°
Percentage balance	9.1
Stick gearing, deg/in.	4.1

The underlying theory of the entire 190 design appears to be to reduce field maintenance time to a minimum, as though the plane had been created with the idea that it is quicker to get parts replaced than to repair them.

Furthermore, the design is such that the aircraft could be, and was, built through widespread use of subcontracting and dispersal plants.

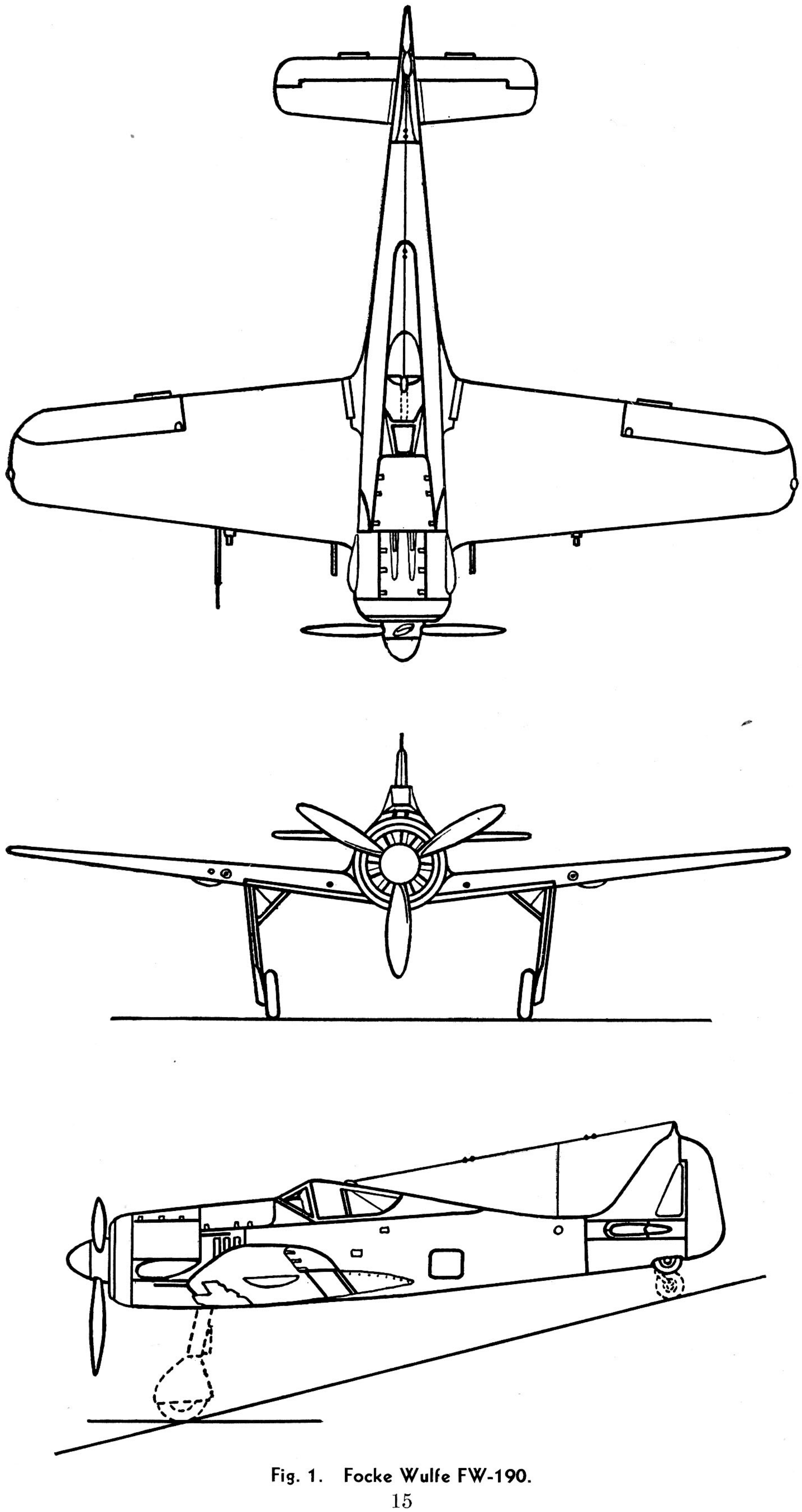


Fig. 1. Focke Wulfe FW-190.

Convair Liner

The Convair Liner has a gross weight of 40,500 lb and a maximum pay load of 9,300 lb, including 40 passengers (7,800 lb) and cargo (1,500 lb). Weight empty is 26,400 lb.

Average cruising speed at 16,000 ft, 1,200 bhp per eng, 38,000-lb weight, is 291 mph. Stalling speed at sea level with full flaps, power off, and maximum landing weight of 38,571 lb, is 89 mph. Maximum range, in addition to 200 miles plus three-fourths fuel reserve, 1,200 bhp per eng, carrying 40 passengers and baggage, with 10-mph head wind, is 760 miles. Maximum take-off wing loading is 49.5 lb per sq ft; maximum take-off power loading, 8.4 lb per bhp.

Dimensions (1): span, 91 ft 9 in.; over-all length, 74 ft 8 in.; height (on ground), 26 ft 11 in.; flap span, 26 ft 8 in. each. Wing area is 817 sq ft; total flap area, 140 sq ft. Mean aerodynamic chord (true) is 9 ft 8.6 in.; main wheel tread, 25 ft.

The transport is powered by two Pratt & Whitney R-2800 CA-18 provided with Convair's exhaust thrust-augmentation system.

Automatically controlled pressurization and radiant wall heating maintains passenger comfort regardless of outside altitudes and temperatures.

The interior arrangement includes space for radio equipment immediately aft of the flight deck, followed by luggage racks, main cabin, lavatory, buffet, and additional cargo space (2).

Outboard of the engines an integral fuel tank is located on either side of the wing.

The plane is provided with hydraulically operated integral stairways, one on the forward starboard side just aft of the flight deck, and the other in the rear fuselage under the tail (3).

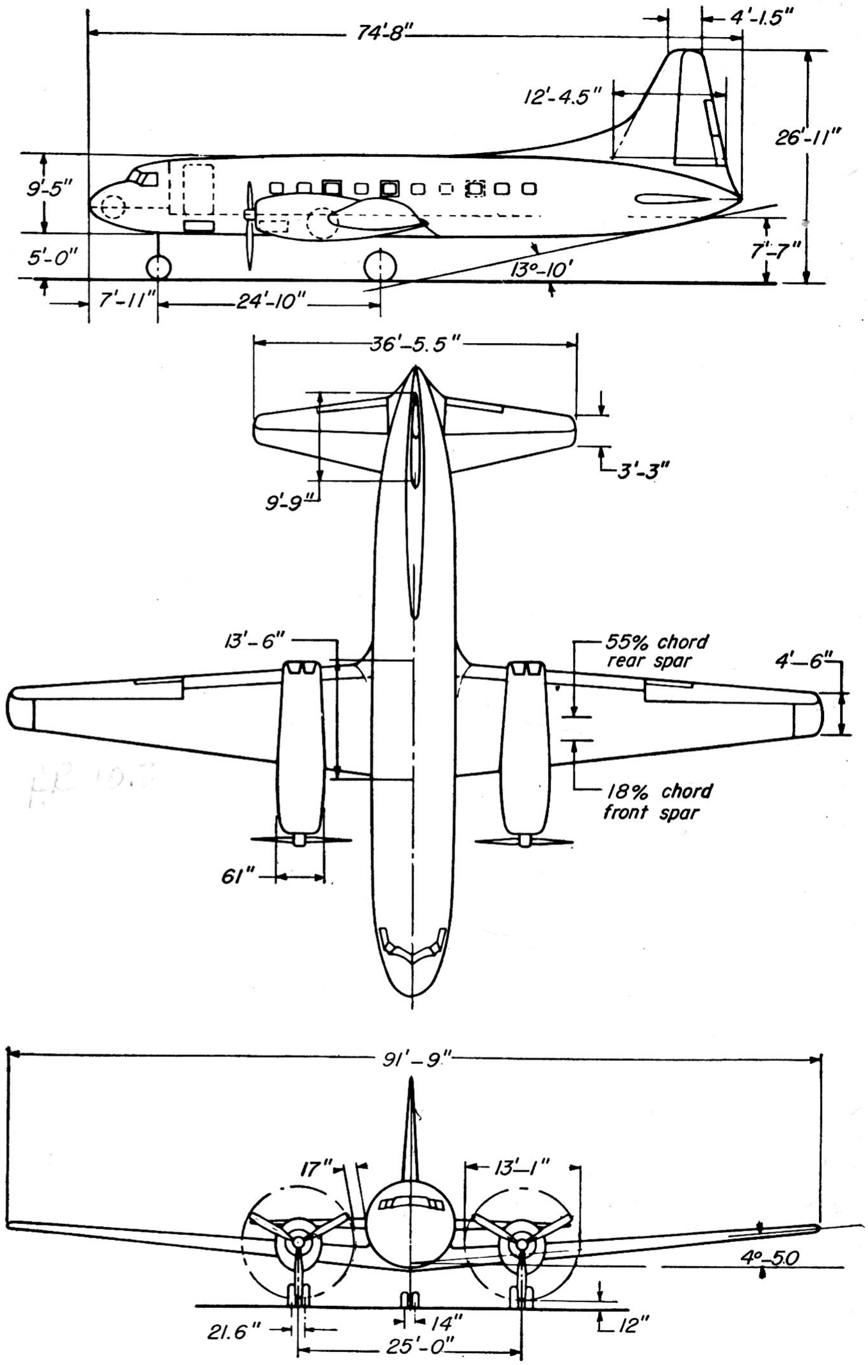


Fig. 1. Three-view drawing of Convair Liner transport.

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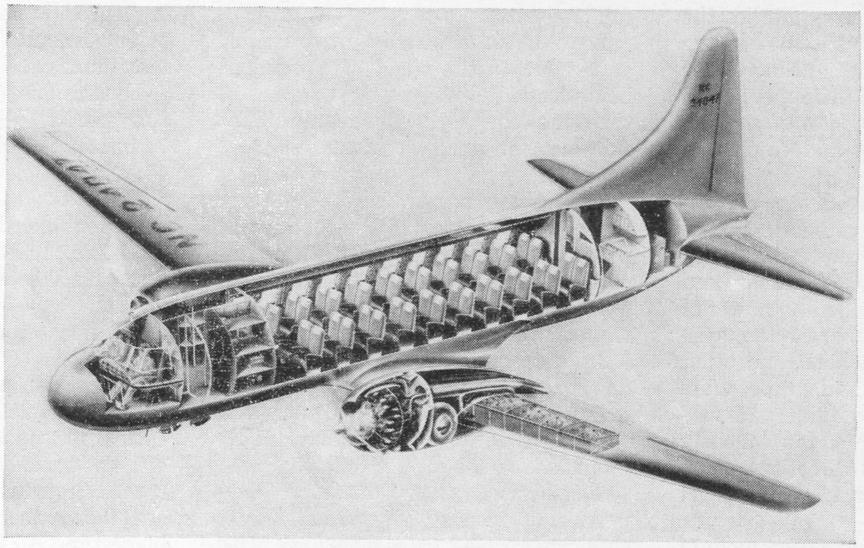


Fig. 2. Cutaway showing the interior arrangement of a Convair Liner.

Fig. 3. The integral loading ramps of the Convair Liner are hydraulically operated.

Fairchild C-82 Packet

Three considerations underlie the Packet design (1): carrying heavy bulky units without dismantling them; transportation of paratroopers and means for rapid conversion of the aircraft to hospital use; and towing of gliders.

Units to be transported were considered to fall into three categories: those which could be loaded under their own power—trucks, tanks, half-tracks, and armored cars; those loaded by power of their own prime movers—cannon, caissons, trailers, field kitchens, and other miscellaneous units; and those units normally carried in containers of various shapes and sizes—advantageously handled when loaded directly from a truck to the Packet's truck-bed-level cargo floor.

The large rear doors accommodate these types of cargo and, because of the high wing and twin-boom and high-tail arrangement, can be approached from the rear and sides of the plane without obstruction.

Since cargo to be transported is predominantly square, the sides and top of the cargo compartment are straight for the full length to obtain the optimum volume of usefulness.

Use of the tricycle landing gear places the cargo floor horizontal for its full length.

Loading is facilitated by two ramps, adjustable to the tread of equipment being loaded, and brought together at the center they form a single ramp unit suitable for loading litter or seat patients.

As a troop carrier, the C-82 affords simultaneous egress for two lines of paratroopers, and coupled with its low controllable speed, permits more than twice the usual concentration of aerial troopers in a given ground area.

In the center of the cargo floor, a door bay permits the dropping of aerial delivery containers carried on rails with electrically operated shackles releasable by pilot or jump master.

The straight walls of the cargo compartment simplify the mounting of supports for litters five tiers high, with sufficient space in the center portion of the fuselage for movement of medical personnel and equipment.

The material of construction in the Packet is generally 24ST alclad, except for higher strength alloy in various highly stressed members.

The maximum pay load is 18,000 lb for 500 miles; 15,500 lb for 1,000 miles, and 13,000 lb for 1,500 miles. Take-off run at sea level with gross weight of 42,000 lb is only 800 ft. The cruising speed is more than 200 mph at 10,000 ft, and the range is 4,000 miles maximum.

Dimensions (2) of the Packet are: span, 106 ft $5\frac{11}{32}$ in.; over-all length, 77 ft 1 in.; height on the ground, 26 ft $4\frac{1}{16}$ in.

Wing area (less ailerons) is 1,288.7 sq ft; root chord, 17 ft 10 in.; tip chord, 8 ft 11 in.; fuselage depth (max.), 13 ft 6 in.; fuselage width (max.), 10 ft $4\frac{3}{32}$ in.

Military crew is five; commercial, two.

The power plants are two Pratt & Whitney R-2800-C twin-row radials, each 2,100 hp at 2,800 rpm for take-off; normal rating 1,700 hp at 2,600 rpm. Propellers are Hamilton standard full-feathering hydromatic three-blade type, 15 ft 1 in. in diameter.

With an unobstructed and continuous cargo compartment capacity of 2,870 cu ft—larger than some railway box cars—the gross weight (provisional) is 50,000 lb or (design) 42,000 lb; weight empty, 28,000 lb; useful load, 22,000 lb.

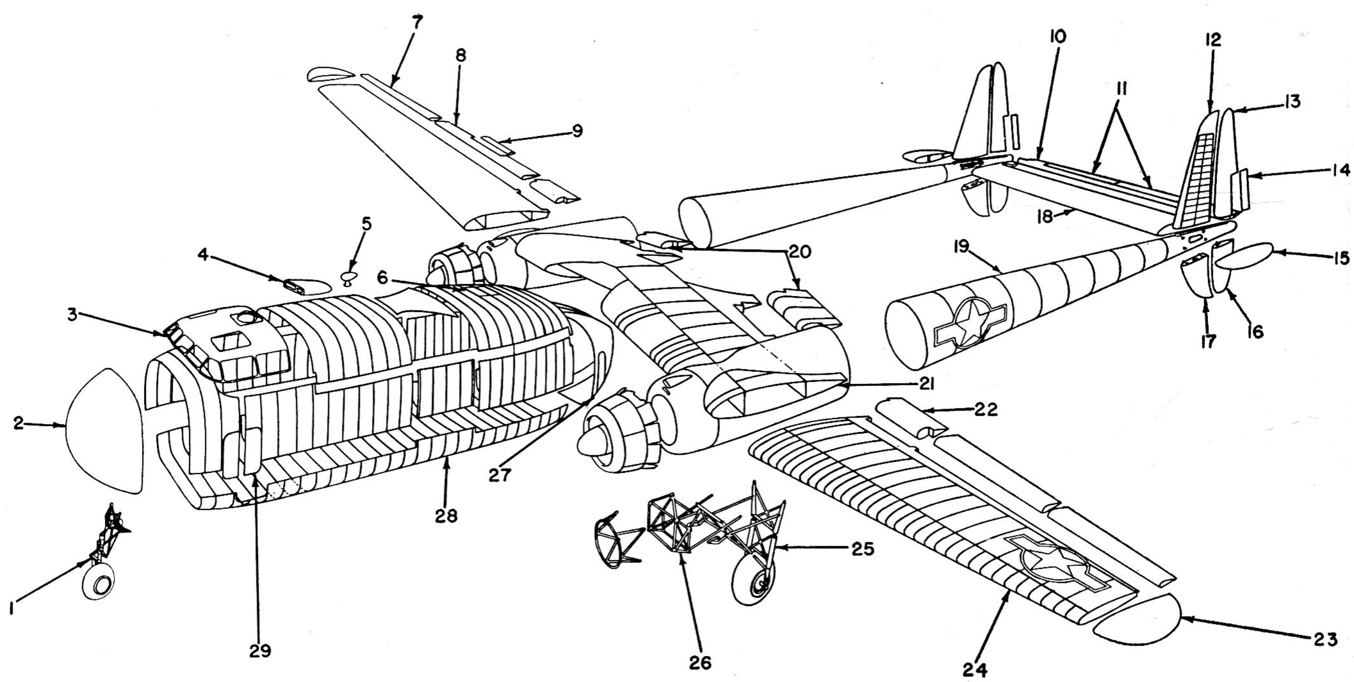


Fig. 1. Exploded view of C-82 showing: (1) nose gear; (2) nose section; (3) cockpit enclosure; (4) scoop; (5) antenna; (6) life-raft door; (7) outboard aileron; (8) inboard aileron; (9) tab; (10) elevator; (11) tabs (spring and trim); (12) upper fin; (13) upper rudder; (14) tab; (15) stabilizer tip; (16) lower rudder; (17) lower fin; (18) stabilizer; (19) boom; (20) inboard flaps; (21) wing center section; (22) outboard flap; (23) wing tip; (24) outer panel; (25) main landing gear; (26) nacelle structure; (27) rear cargo door; (28) fuselage main body section; (29) front cargo door located below cockpit floor.

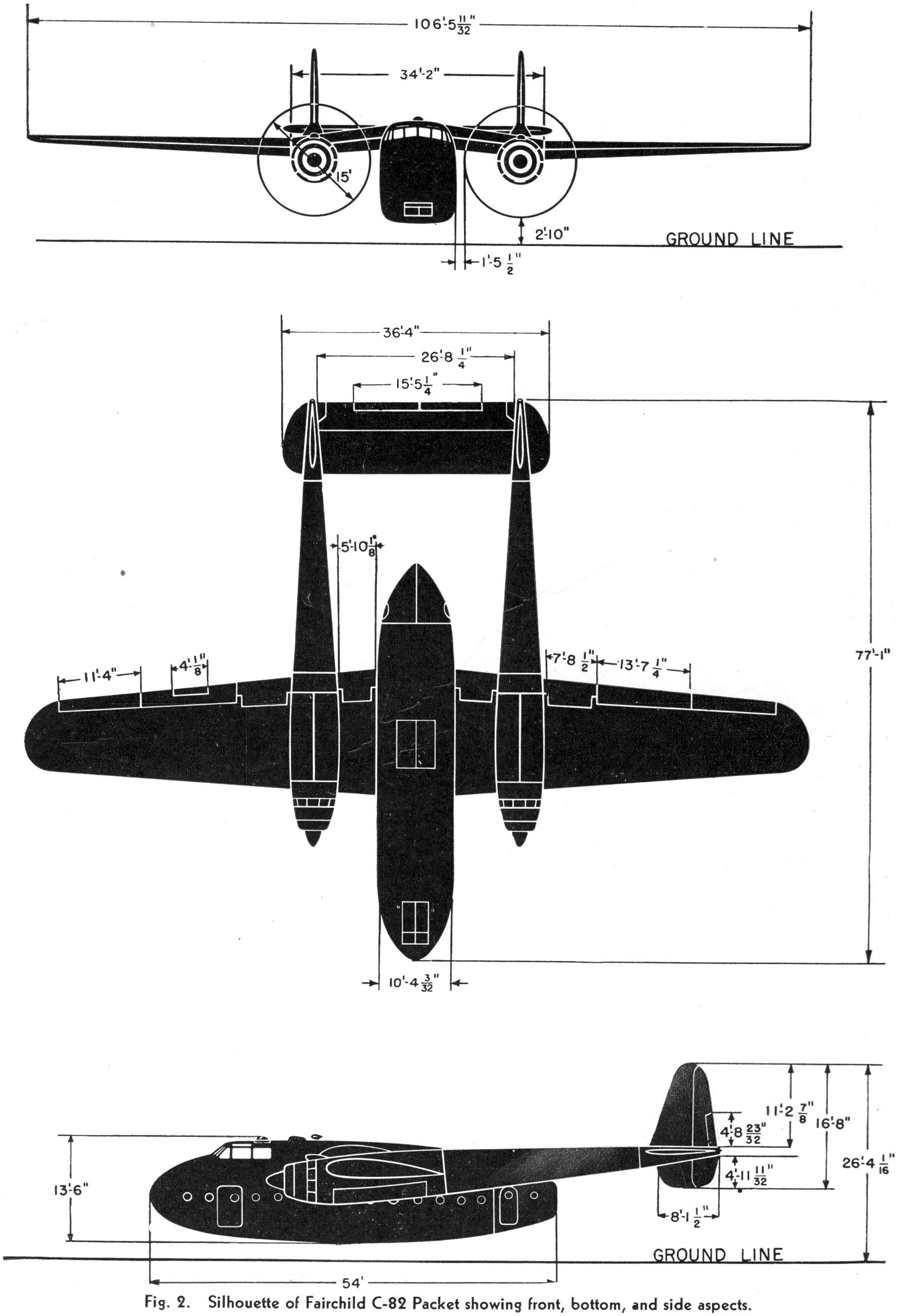


Fig. 2. Silhouette of Fairchild C-82 Packet showing front, bottom, and side aspects.

North American B-25 Mitchell

Designed in 1939 and first flown in 1940, the B-25 medium bomber series earned an enviable reputation in the hands of Allied Nations pilots in all theaters of the Second World War. The latest models of the Mitchell to enter combat were the B-25H, outstanding among production planes for its extremely heavy armament, and the B-25J, latest improvement on the original medium bomber design (1).

The Mitchell was manufactured on the basis of 48 major assemblies, any one of which, theoretically, could be modified without necessarily affecting the other 47. The B-25 has undergone nearly a dozen such changes without altering the basic design.

In both models, fire power has been increased by the addition of a tail turret, waist guns, moving the upper turret forward to improve the field of fire, and two fixed forward-firing package guns on each side of the pilot's compartment.

The nose of the B-25H is fitted with four machine guns and a 75-mm cannon; the B-25J has two machine guns—one flexible and one fixed—protruding from the bombardier's enclosure.

The tactical purpose of the B-25H is primarily for low level attack and the destruction of land or naval materiel targets in support of air, ground, and naval forces. As a dual-purpose plane, it can knock out surface forces protecting the target, then proceed to bomb the target from low altitudes. The B-25J is primarily a medium bomber, nevertheless it is capable of dealing with surface forces.

In spite of their versatility, the B-25's basically remain unchanged from the original. They are semi-monocoque mid-wing monoplanes powered with two Wright 1,700-hp fourteen-cylinder engines. All fixed surfaces are metal-covered. Flight control surfaces, exclusive of wing flaps, are heavily doped, fabric-covered members. Countersunk rivets are used on the forward third of fuselage skin and fixed surfaces to reduce drag, and brazier-head rivets on the aft two-thirds.

Normal entrances and exits consist of two hatches in the belly, one under the upper turret compartment, the other aft of the waist gunner's position. Automatically retracting stepladders are provided.

Escape hatches are for use in crash landings when the main entrance hatches are blocked, or under emergency conditions while the plane is in flight.

The crew for the B-25H consists of a pilot, upper turret gunner, cannoneer-navigator, waist gunner, and tail gunner. Pilot, copilot-navigator, bombardier, upper turret gunner, waist gunner, and tail gunner man the B-25J.

Both bombers carry considerably more armor plate than previous models to afford maximum protection for the crew and vital equipment. Provided also are a rubber lifeboat, emergency equipment, pyrotechnics, and the usual oxygen equipment.

Fundamental design information covering the B-25H and B-25J (2) is as follows:

	B-25H	B-25J
Over-all length (max.)	51 ft 3.75 in.	53 ft 5.75 in.
Height (max.)	16 ft 4¾ in.	Same
Span	67 ft 6.704 in.	Same
Wing area (less ailerons)	577.67 sq ft	Same
Length:		
Root chord	154.600 in.	Same
Tip chord	64.257 in.	Same
Fuselage:		
Depth (max.)	7 ft 4 in.	Same
Width (max.)	4 ft 8.5 in.	Same
Load factor (ultimate)	5.5	Same
Normal gross weight	28,330 lb	27,000 lb

Performance Data

	B-25H	B-25J
Critical altitude	13,000 ft	14,500 ft
High speed (at critical alt., normal power)	293 mph	292 mph
Service ceiling	23,800 ft	25,500 ft
Climb to 10,000 ft	6.8 min	6.1 min
Service ceiling (1 engine)	6,600 ft	6,900 ft
Take-off run to clear 50 ft	2,700 ft	2,410 ft
Landing distance over 50-ft obstacle	2,450 ft	2,210 ft
Max. rate of climb (military power at sea level)	1,950 fpm	2,090 fpm

WEIGHTS, POUNDS

	B-25H	B-25J
Wing group:		
Center section	1,826	1,788
Outer panels	924	860
Tips	16	16
Ailerons	98	100
Flaps	172	174
Total	3,020	2,938
Tail group:		
Stabilizer	188	196
Elevators	126	126
Fins	110	101
Rudders	86	85
Total	510	508
Body group:		
Fuselage	2,082	1,955
Landing gear:		
Main	1,578	1,562
Nose	260	274
Bumper	12	12
Total	1,850	1,848
Nacelle group:		
Nacelles	960	914
Power-plant group:		
Engines, installed (two)	4,000	3,935
Accessories	358	217
Controls	188	113
Propellers and spinners (two)	904	973
Starting system	102	90
Total	5,552	5,328
Lubricating system:		
Tanks and protection	201	200
Piping, etc	96	243
Total	297	443
Fuel system:		
Tanks and protection	1,200	1,025
Piping, etc	280	284
Total weight, power-plant group, lubricating and fuel systems	7,329	7,080
Fixed equipment:		
Instruments	126	101
Surface controls	390	423
Hydraulic system	210	186
Communications (AAF)	235	284
Armament	2,035	2,089
Furnishings	484	554
Electrical	612	525
Anti-icing (defrosting tubes)	81	75
Total	4,173	4,237
Unit weights:		
Wing group (net area 609.8 sq ft), lb/sq ft	4.95	4.82
Tail group (net area 223.4 sq ft), lb/sq ft	2.28	2.27
Lubricating system per gal oil (75 gal)	3.96	5.91
Fuel per gal (974 gal)	1.52	1.34
Gross weights:		
Normal gross weight	28,330	27,000
Alternating gross weights	33,047–36,600	31,737–35,831
Total weight empty	19,924	19,480

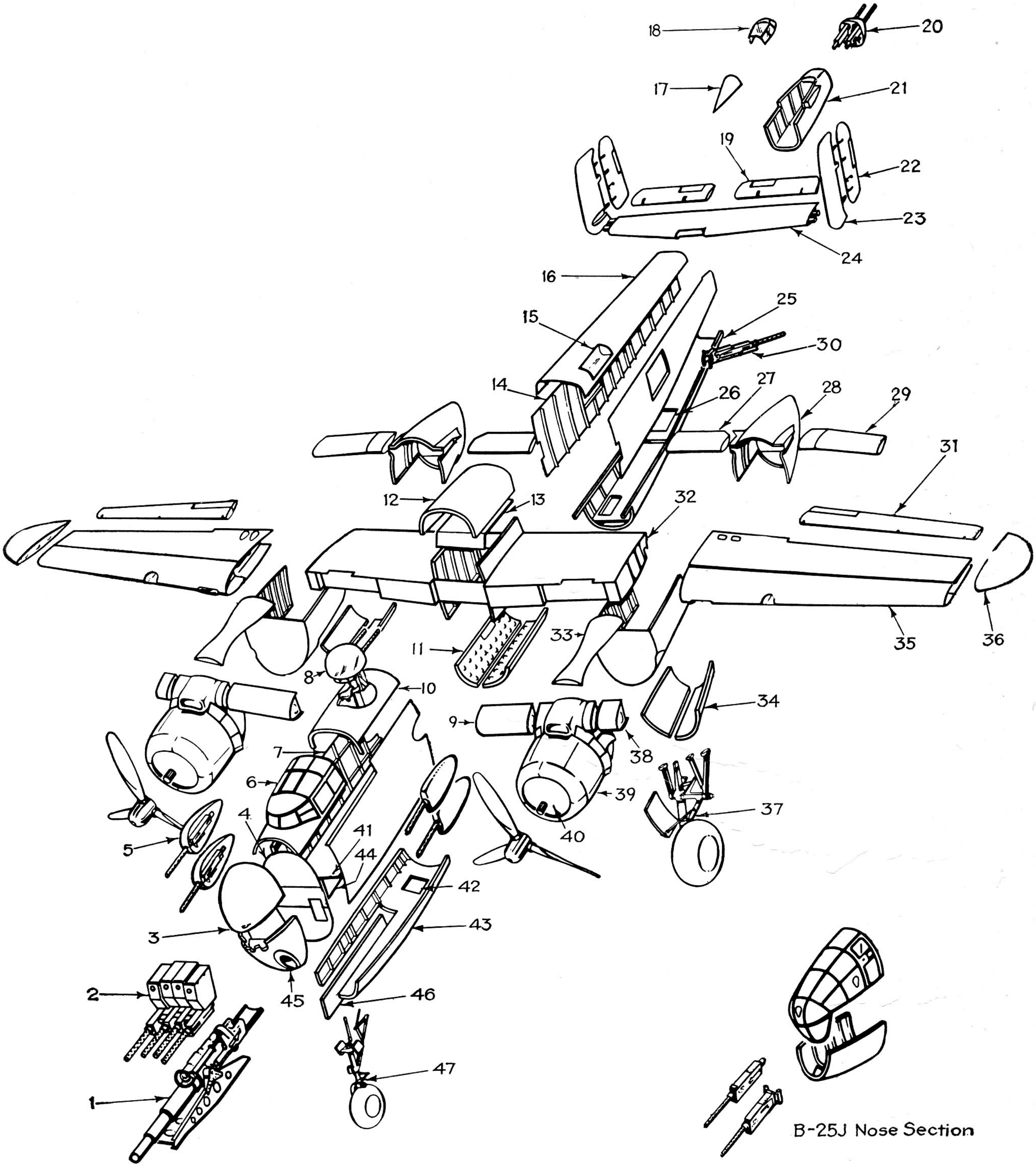


Fig. 1. Exploded view showing details of B-25H and B-25J: (1) 75-mm cannon installation; (2) four fixed .50-caliber nose guns (B-25H); (3) nose assembly hood; (4) bulkhead; (5) .50-caliber blister guns; (6) pilot's enclosure; (7) fuselage front, side frame; (8) Bendix upper turret; (9) nose assembly, inboard center section; (10) fuselage front, top frame; (11) bomb-bay door; (12) fuselage top frame; (13) bomb-bay passageway floor; (14) rear fuselage side frame; (15) life raft; (16) rear fuselage, top frame; (17) horizontal stabilizer upper fairing; (18) tail gunner's canopy; (19) elevator; (20) Bell tail turret; (21) tail gunner's compartment; (22) rudder; (23) vertical stabilizer; (24) horizontal stabilizer; (25) rear fuselage, bottom frame; (26) rear entrance hatch; (27) inboard flap; (28) nacelle; (29) outboard flap; (30) .50-caliber waist gun; (31) aileron; (32) wing center section; (33) nacelle upper fairing; (34) main landing gear doors; (35) outer wing panel; (36) wing tip; (37) main landing gear; (38) nose assembly, outboard center section; (39) cowling; (40) power plant; (41) pilot's floor; (42) front entrance hatch; (43) fuselage front, bottom frame; (44) fuselage beam; (45) lower nose assembly (B-25H); (46) nose landing gear door; (47) nose landing gear. The nose section of the B-25J shown at the lower right has fixed and flexible .50-caliber guns.

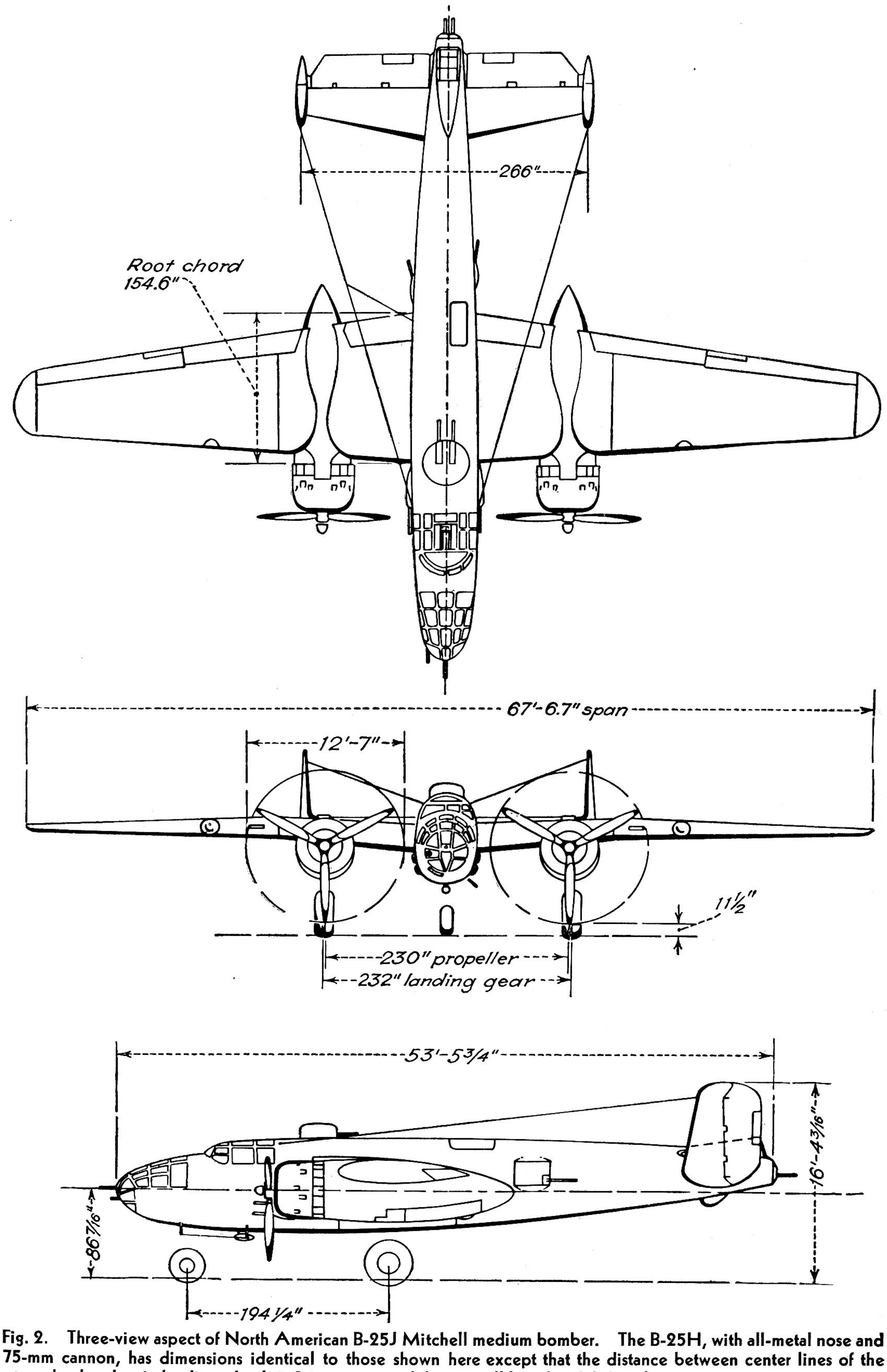


Fig. 2. Three-view aspect of North American B-25J Mitchell medium bomber. The B-25H, with all-metal nose and 75-mm cannon, has dimensions identical to those shown here except that the distance between center lines of the nose wheel and main landing wheels is 2 in. greater and the over-all length is 2 ft 2 in. less.

Martin 2-0-2 Transport

A high-performance, medium-range, twin-engined transport, the Martin 2-0-2 is designed for maximum efficiency and economy of operation (1).

Accommodating 36 passengers with cargo volume of 342 cu ft, it has a practical operating range of 930 miles. Cruising speeds up to 280 mph can be obtained at 10,000 ft, and the 2-0-2 can operate out of smaller fields than comparable aircraft, being certificated by CAA for take-off runway length of only 3,510 ft with full load at sea level.

The Martin-designed low-drag, high-lift wing is a major factor contributing to this performance. The airfoil is mathematically developed to provide a high-lift coefficient with low drag at all operating speeds.

The fuselage is of semimonocoque construction combining great structural strength with light weight. The cabin is soundproofed and insulated. It has an automatic fresh-air, warm-wall heating and ventilating system, providing 50 cu ft of air per minute per person, and maintains room temperatures as low as 40°C.

Pratt & Whitney R-2800 engines power the plane, turning Hamilton standard three-blade reversible propellers, 13 ft 1 in. in diameter.

Specifications of the 2-0-2 include: gross weight (with water injection), 39,900 lb (dry engine, 39,100 lb); max. landing weight (water injection), 38,000 lb (dry engine, 37,200 lb); weight empty (water injection), 25,079 lb (dry engine, 24,984 lb); operating weight empty (water injection), 26,811 lb (dry engine, 26,611 lb).

Capacity, cargo and baggage, 342 cu ft; fuel, 1,000 gal; design useful load (with water injection), 14,821 lb (dry engine, 14,116 lb); max. pay load (with water injection), 9,089 lb (dry engine, 9,289 lb); pay load for max. range (water injection), 7,089 lb (dry engine, 6,489 lb); pay load at 800 miles, 1,080 bhp, reserve fuel for 200 miles plus 45 min (water injection), 8,155 lb (dry engine, 7,550 lb).

Wing area 864 sq ft; aspect ratio, 10.0; airfoil section, GLM-W-16.

Length of main cabin, 34 ft 8 in.; minimum width, 9 ft; height, 6 ft 7 in.

Center of gravity limitation, gear up, 12.4 per cent M.A.C. forward and 37.0 per cent M.A.C. aft.

Propeller-to-ground clearance, 12.5 in.

Dimensions are: over-all length, 71 ft 4 in.; wing span, 93 ft 3.32 in.; tread, 300 in.

Wing has 10-deg dihedral at quarter chord; tail, 8-deg dihedral.

Electrical fire and smoke detectors provide fire warning; photoelectric cell smoke detectors are used in cargo areas; thermocouple detectors in the nacelles and heater compartment.

Thermal anti-icing equipment is used on the 2-0-2 surfaces. Heat source is four internal-combustion heaters located in the nacelles. Propellers are electrically deiced.

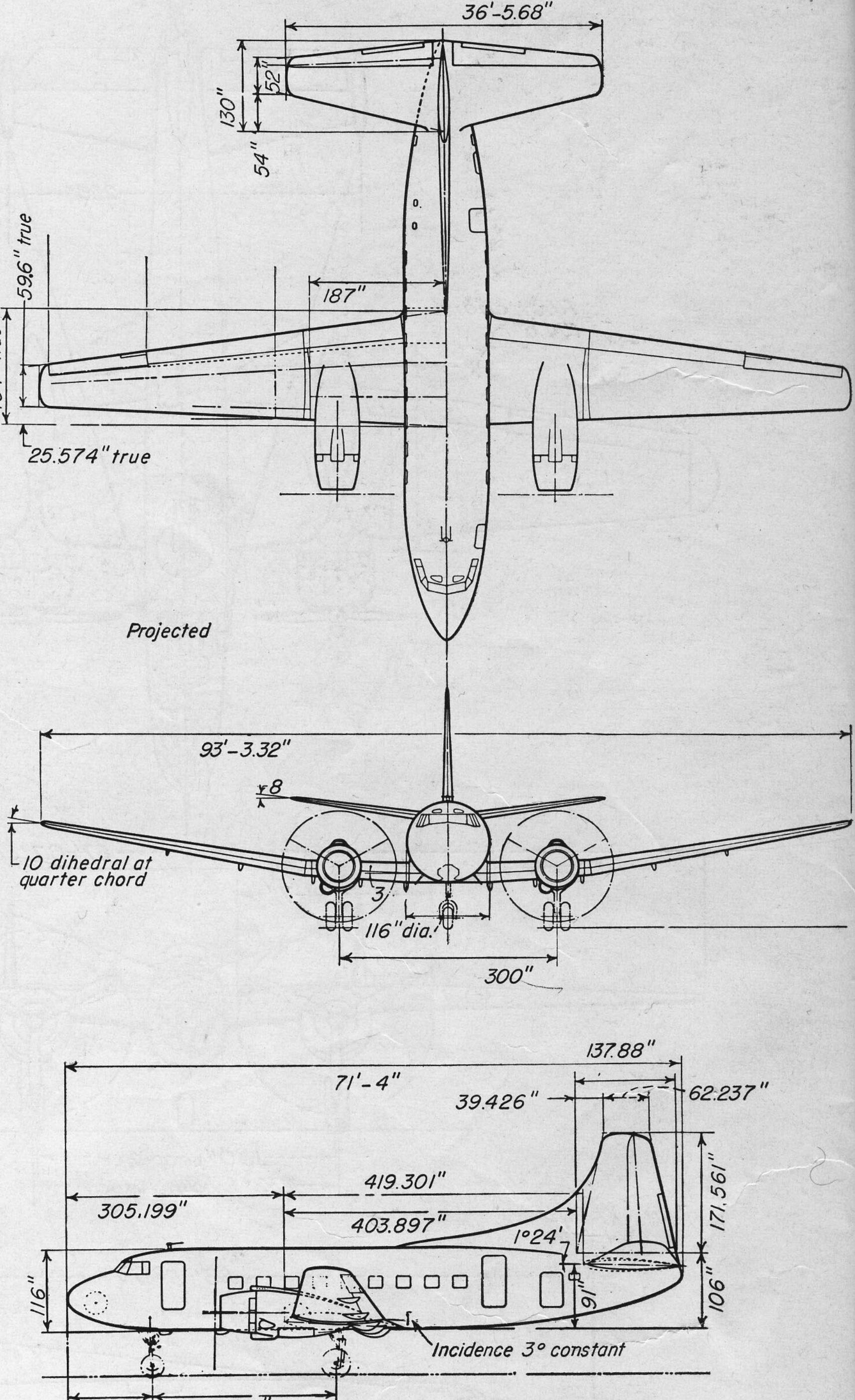


Fig. 1. Three-view drawing of a Martin 2-0-2.

Messerschmitt Me-262

The jet-powered Me-262 (1), which caused clammy sweat to stand out on the brows of Allied air strategists and commanders of the bomber fleets that were pounding Germany early in 1944, is an unusual combination of radical and orthodox design, materials combinations, and workmanship. It shows, too, that the production engineer had an important place in its development, second only, perhaps, to Hitler, whose insistence on a bomber modification delayed the jet plane's operational use by a year and thus saved the American and British bomber offensive from being blunted and even stopped altogether.

Basic Design Information

Span	40 ft 11½ in.
Length	34 ft 9 in.
Height (fin above ground)	11 ft 4 in.
Wing area (approx.)	270 sq ft
Chord:	
Root	8 ft 4 in.
Tip	2 ft 9¾ in.
Aspect ratio	7.5
Wing loading	44.5 lb
Weight empty	8,514 lb
Useful load	7,106 lb
Gross weight	15,620 lb
High speed (red line)	658 mph
Range	50–90 min
Max. thickness	35% of chord
Max. permissible c.g	30% M.A.C.

A low-wing monoplane (2), it was Germany's most successful jet-propelled aircraft. Used principally as a day and night fighter (3), it was apparently also designed for photoreconnaissance use.

The very tip of the fuselage looks exactly like a propeller spinner—and may well be just that—with a hole cut in front so that a gun camera can be mounted inside, reached by a small, quickly removable access plate set in the left side. A solid web bulkhead backs this section up and serves as a jacking point. Then follows a section 14½ in. long enclosing a flush-riveted channel-shaped former, the whole being screwed to the next section which contains the nose wheel and the four 30-mm MK-108 cannon grouped high in the nose section (4).

Since the length of these guns is but 3 ft 6 in., a very compact installation has been achieved with no external projections. A large spherical support around the barrel near the aft end facilitates adjustments during sighting in operations.

The guns usually are set to converge at 450 meters. The MK-108 fires 575 to 600 rounds per minute with a muzzle velocity of 1,570 fps and weighs but 134 lb. Compressed air for charging is carried in eight bottles set inside the fuselage on the left forward of the cockpit.

The two top guns carry 100 rounds each, the bottom pair 80 each, and all are fired simultaneously by a switch on the contact stick.

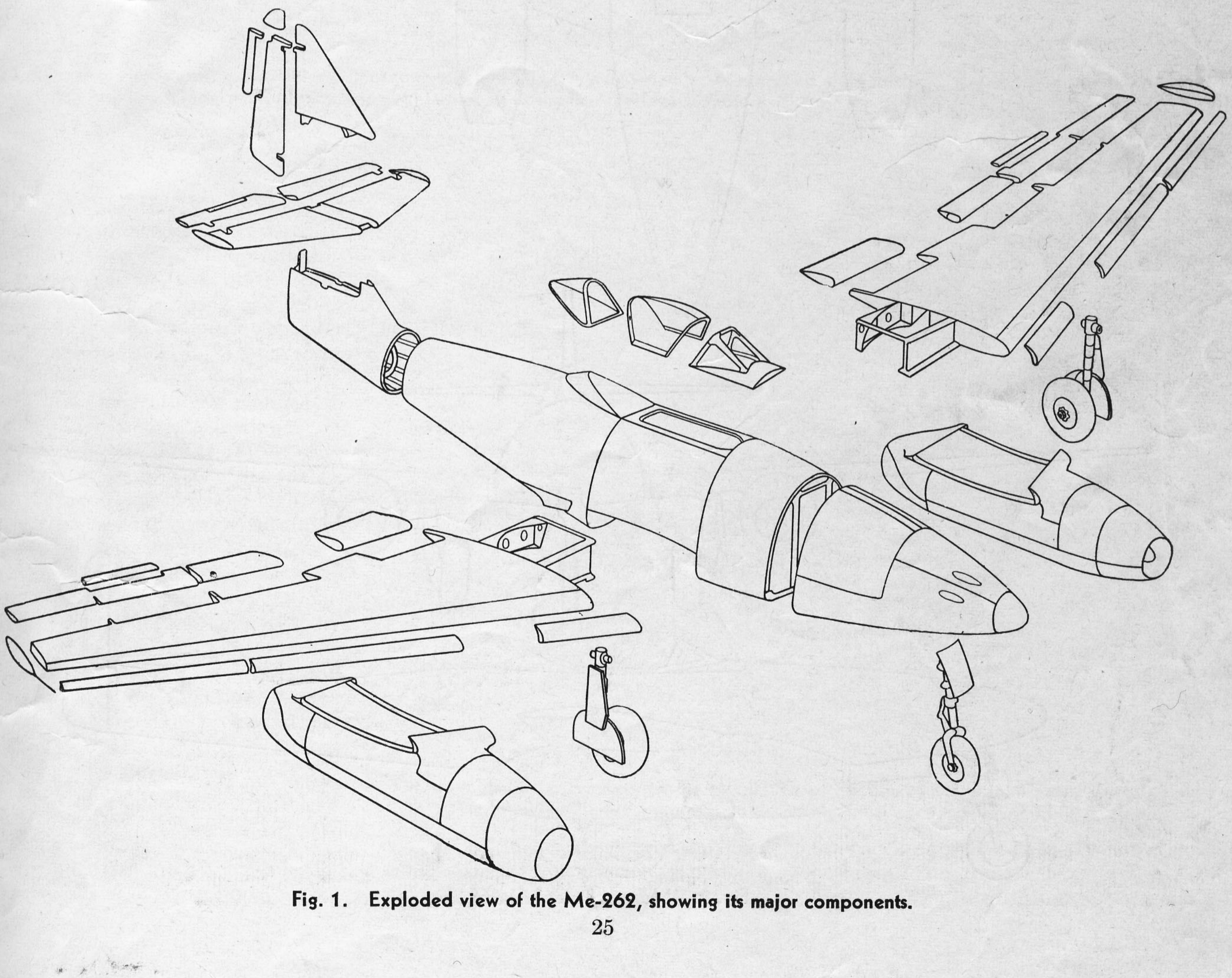


Fig. 1. Exploded view of the Me-262, showing its major components.

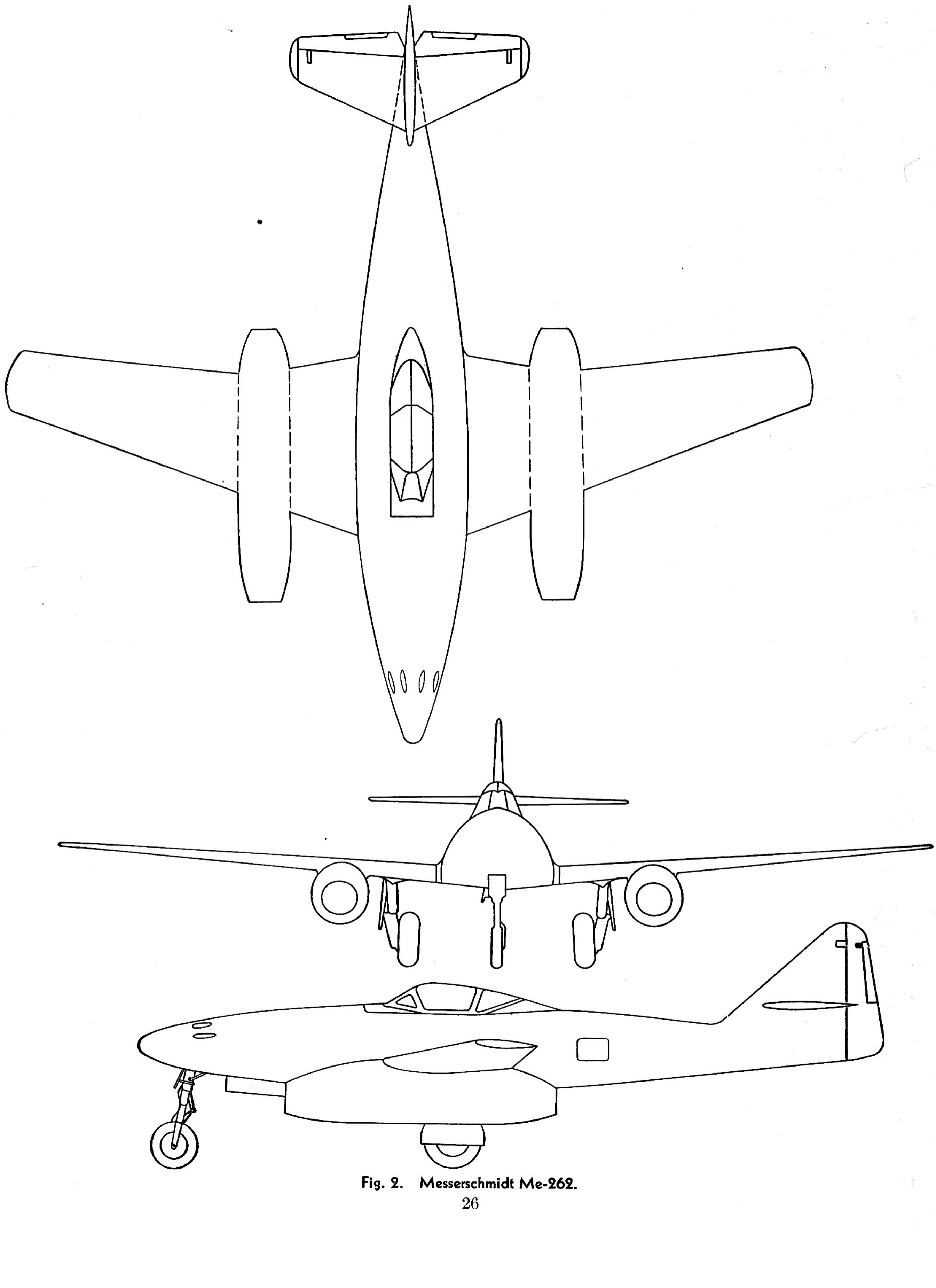


Fig. 2. Messerschmidt Me-262.

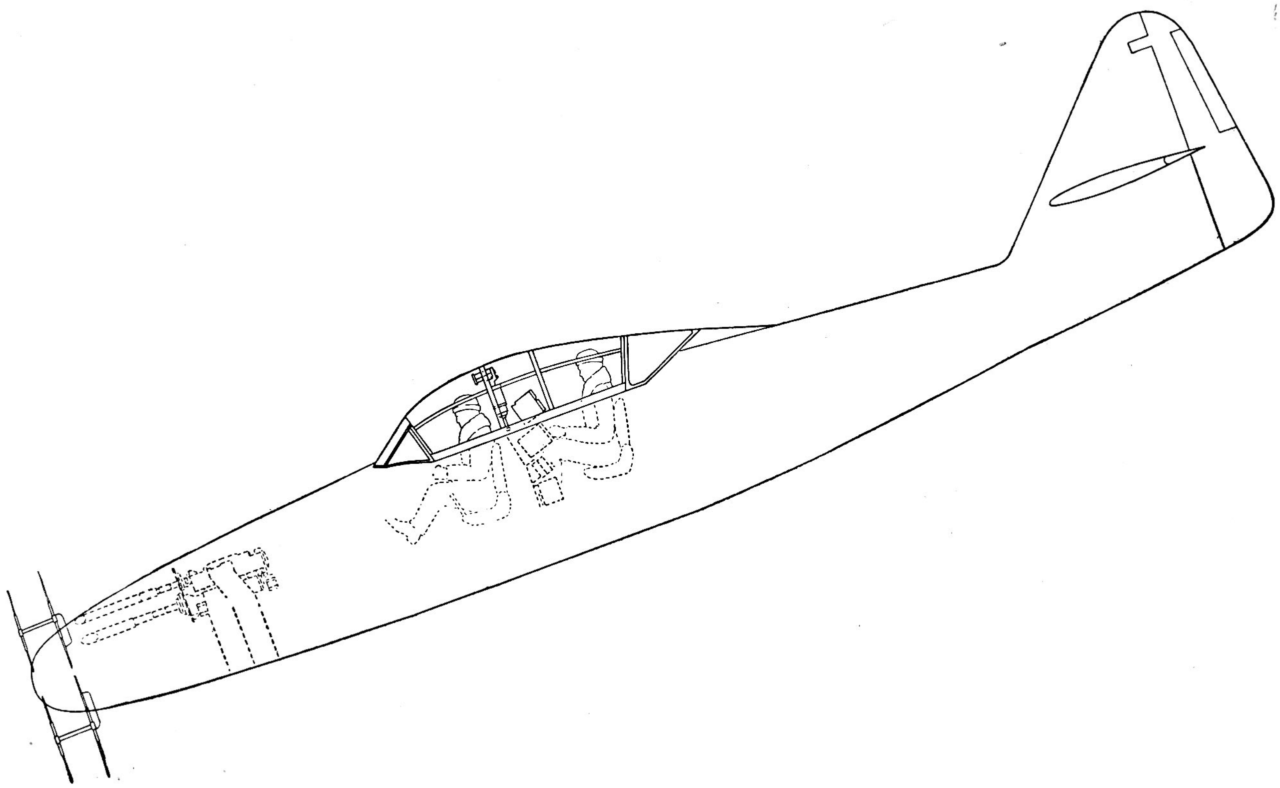


Fig. 3. Phantom view showing the final modification—the Me-262-B2, a two-man radar-equipped night fighter. The addition of an extra seat meant moving fuel tanks, radio, and other equipment farther aft in the rear fuselage section.

Although the ME-262 was designed as an interceptor, Hitler ordered it made into a bomber. This resulted in the installation of two jettisonable bomb racks, each carrying one 550-lb bomb. Additional armament on later models consisted of 24 R4M 5-cm rockets, 12 under each wing, and it was reported that the Germans planned to install up to 48 under each wing.

Skin of the section, 6 ft 5½ in. long, aft of the spinner is of .080 sheet steel. Since the cannon are mounted high, the use of steel in that section is understandable because of the blast effect, but even the belly skin is of the same material. It is possible that the employment of steel was dictated by transportation difficulties rather than design considerations or lack of aluminum, for later investigation showed that the Nazis were not pressed at any time for this material. However, since the nose section carried both the heavy armament and the nose wheel, the added strength of steel may have been a deciding factor.

The cannon are most accessible, for two access doors, 35¼ in. long, piano-hinged 1½ in. off the top center line, can be opened quickly simply by loosening two flush toggle latches like those used on the cowling of the FW-190, exposing all the gun mechanism as well as the ammunition drums.

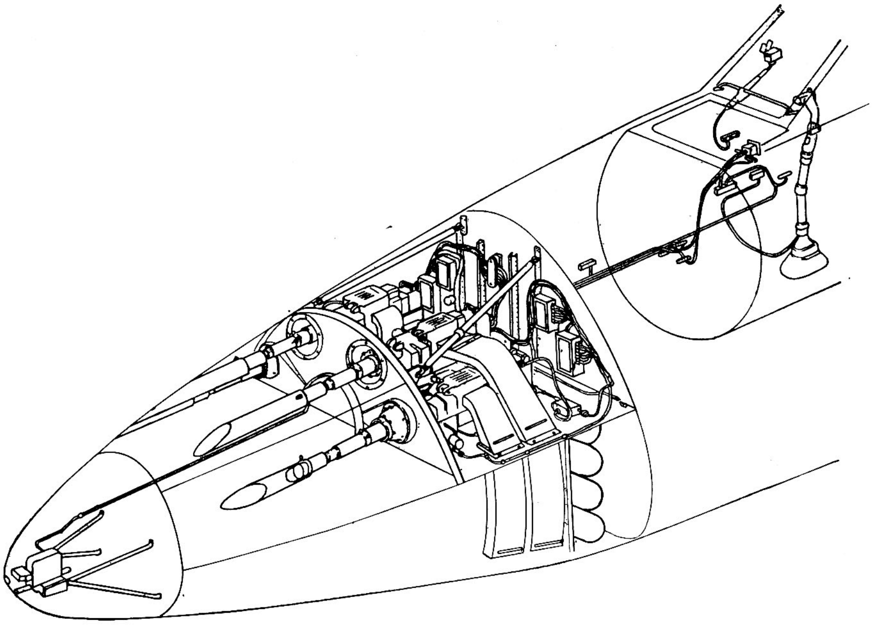


Fig. 4. Phantom view showing the installation of the gun camera in the nose, four 30-mm MK-108 cannon, with ejector shutes below, and electrical connections for firing.

Douglas A-20

The A-20 has seven major components: nose, main fuselage, empennage, right and left outer wing panels, and right and left inner wings.

The fuselage is a semimonocoque all-metal structure comprised of extruded 24S aluminum alloy longitudinals, spaced 4 to 8 in. apart, and formed of 24ST alclad sheet, channel-type frames, spaced 12 to 24 in. apart. At highly stressed points, the frames are built up of extruded sections and sheet-aluminum alloy gussets. The alclad 24ST sheet covering is attached to the frames with flush rivets and stiffened by longitudinals.

Lap joints are used, with vertical laps either joggled to make a smooth contour or, in the case of heavy sheets, beveled along the outer edge.

The semimonocoque design was chosen because it combines the required strength with the least weight and is simpler to manufacture.

As a night fighter or "intruder," the interchangeable nose feature provided a means of installing detection equipment, including a powerful searchlight with which the RAF Bostons pointed out and momentarily blinded crews of enemy planes in order to get in the first shot. The rugged and roomy fuselage made possible additional armament, including a belly tub with machine guns or cannon, also extra fuel tanks for long-range operations.

The strength designed and built into the outer wings permits the installation of wing racks to carry additional bombs. Further, the unusually large bomb bay provides space for additional racks for large numbers of small fragmentation bombs. Three escape hatches are provided for emergency use (1).

Carrying a crew of three and equipped with an attack nose in which six .50-caliber machine guns are mounted, with upper rear and lower gun positions, and having close to single-seat fighter speed and maneuverability, the A-20 becomes a hard-hitting, pugnacious day fighter.

Such an airplane, of course, could not be designed in entirety back in 1938, when the first model was built. But from that original 11,850-lb twin-engine, 280-mph aircraft, armed with four fixed guns, one upper and one lower, all of .30 caliber, has come, through two succeeding series, the final A-20.

The 7B was followed by the DB-7 which, in turn, gave way to the DB-7A for export and the A-20A for the AAF. The principal differences between the DB-7 and the DB-7A were larger and more powerful engines and larger tail surfaces.

The A-20A, which was the immediate forerunner of the versatile A-20 series, was designed for a gross weight of 19,750 lb, carried a crew of three, and was armed with four forward-firing fixed machine guns, an upper flexible twin-gun installation, and a single gun in the lower rear position, all of .30 caliber.

In the final series (often modified) the A-20 (2), (4) is an all-metal mid-wing monoplane with an over-all wing span of 61 ft 4 in., over-all length with the bombardier nose of 47 ft 4 in., and 48 ft with the attack nose. Over-all height at rest is 18 ft 1 in. The main gear tread is 203½ in. (3).

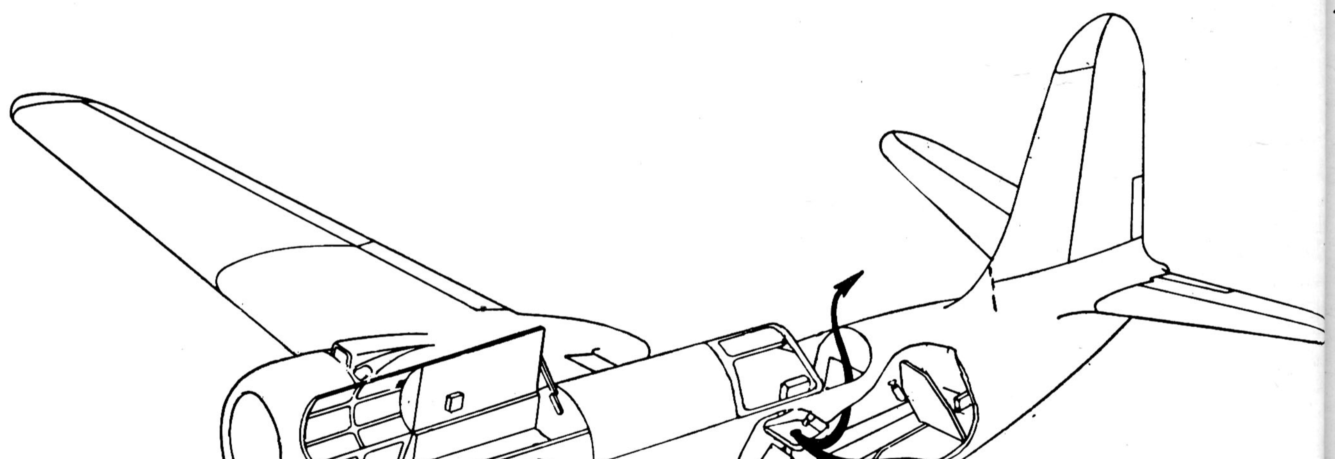


Fig. 1. Emergency exits on the A-20. Controls for fuel dump, bomb dump, and landing gear emergency release are at the right of the pilot's seat. The bomb-door control is at the left of the seat for emergency opening. A fireman's ax and extinguisher are behind the seat. The heavy arrow shows the means of exit. Rear gunners can leave by either top or bottom exits as shown.

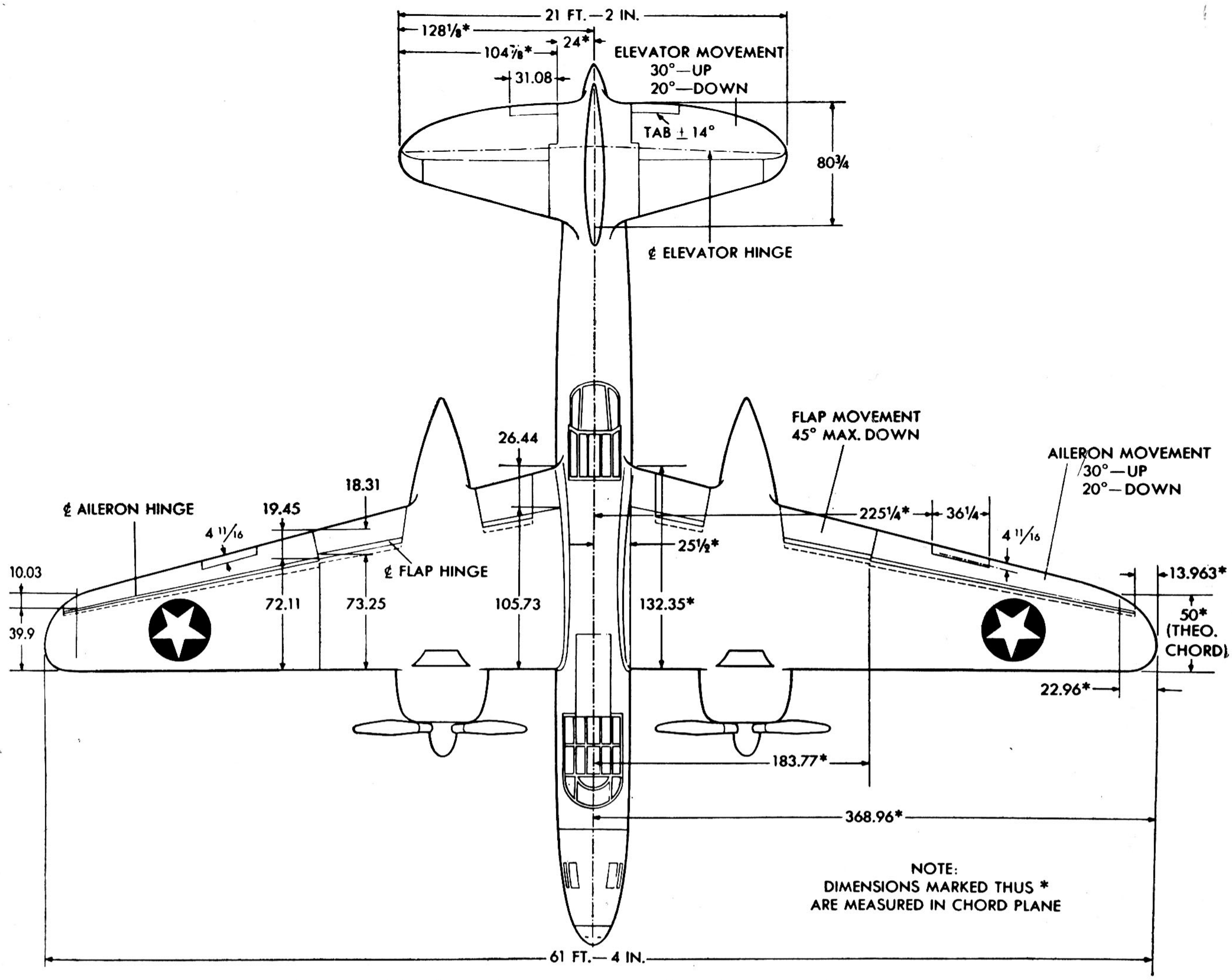


Fig. 2. Plan view of the A-20 showing wing and tail configuration and pertinent dimensions.

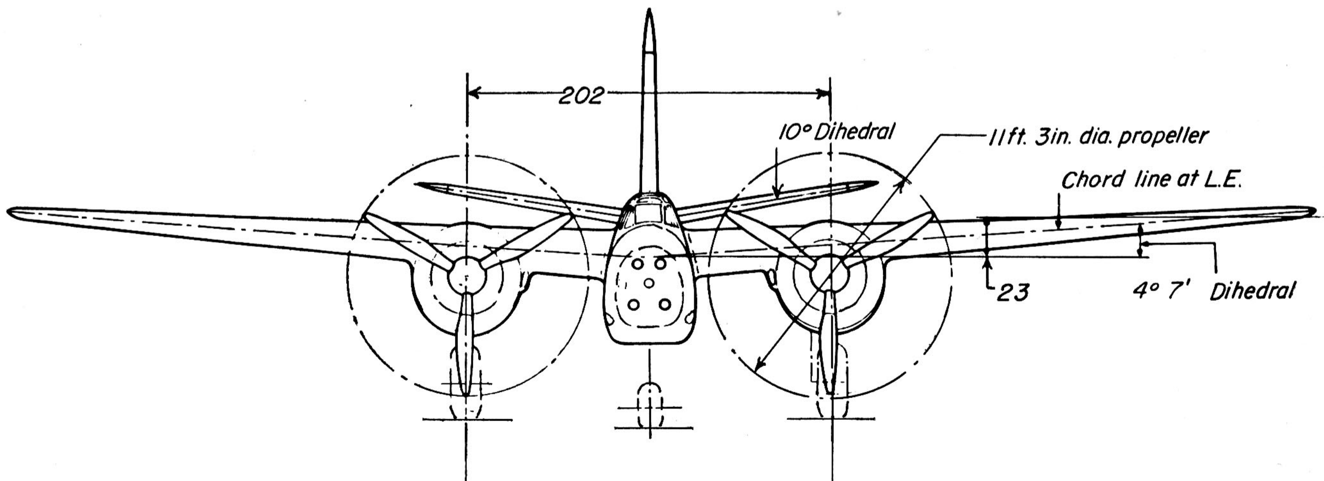


Fig. 3. Front view of the A-20 showing wing and tail dihedral, propeller disk diameter and location, and landing gear tread.

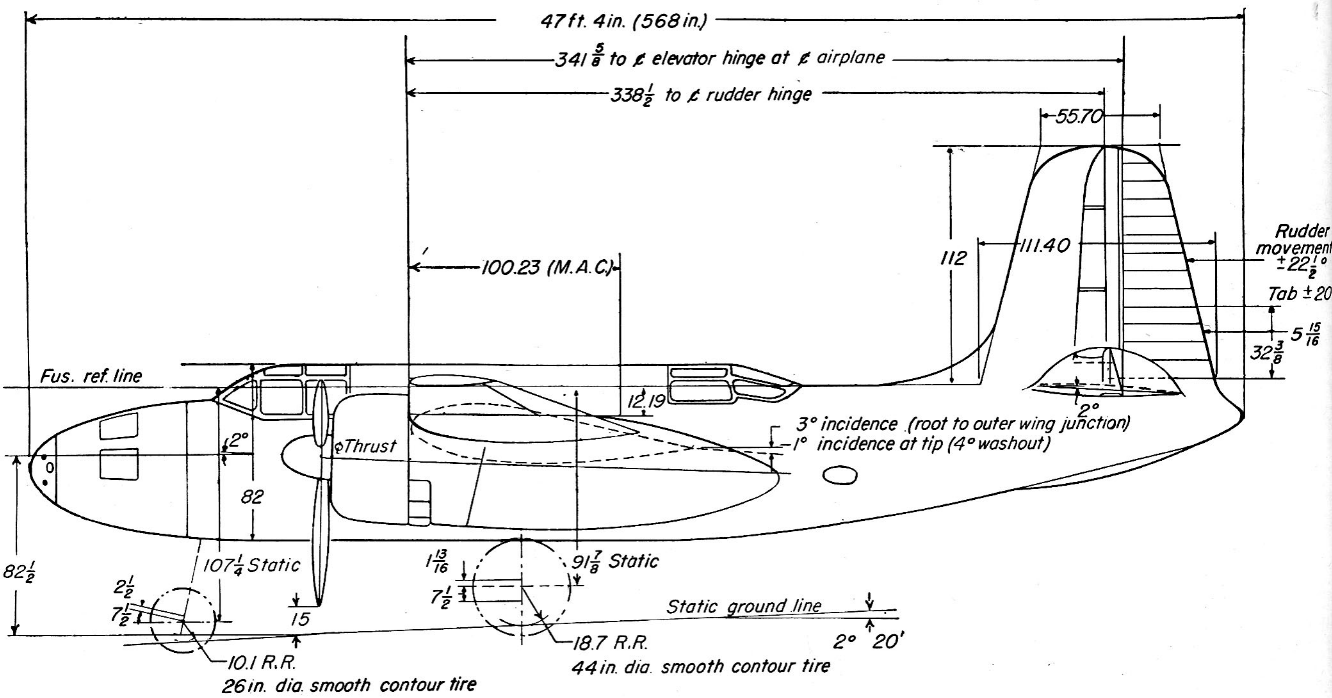


Fig. 4. Profile view of the A-20 showing general design features.

Two fourteen-cylinder 1,600-hp Wright GR2600 engines drive Hamilton standard hydromatic propellers of 11 ft 3 in. in diameter.

Useful loads include: fuel, 540 gal (3,300 lb); oil, 40 gal (300 lb); fixed armament (with 2,100 rounds of ammunition weighing 654 lb), 1,099 lb; and flexible armament (with 1,200 rounds of ammunition weighing 373 lb), 590 lb.

Unit weights are: fuel system, empty, per gallon of capacity, 2.3 lb; oil system, empty, per gallon of capacity, 8.5 lb; wing group, 464.8 sq ft, 5 lb per sq ft; tail group, 184.1 sq ft, 2.2 lb per sq ft.

Balance factors are as follows: attack condition, gross weight—c.g. location, wheels up, aft leading edge M.A.C. 30.7 per cent M.A.C.; c.g. location, wheels up, below L.E. M.A.C. 15.6 per cent M.A.C.; c.g. location, wheels down, aft L.E. M.A.C. 29.4 per cent M.A.C.; c.g. location, wheels down, below L.E. M.A.C. 17.3 per cent M.A.C.

Flying balance range of A-20, between 16 and 33 per cent M.A.C. (wheels down or up).

At design gross weight of 19,750 lb limit maneuver load factors are: positive maneuver load factor, 4.0; negative maneuver load factor, −2.0. Limit gust load factor, flaps up, positive, 4.0; flaps down, positive, 2.27. Limit landing factor at design gross weight is 3.33 and limit diving speed, 12 per cent of maximum level flight speed. Load factor ultimate is 6 G.

Lockheed P-38

Called the most controversial airplane ever adopted by the United States armed services, the P-38 legends may be traceable to the superlative requirements contained in the AAF specifications.

To meet or surpass those requirements, and later to modify the P-38 as war experience and developments required, it was necessary to do considerable pioneering. Particularly was that true in the higher speed ranges then prevailing.

The P-38 was the first modern fighter equipped with tricycle landing gear; the first equipped with a turbosupercharger; the first to use the Allison engine; the first in the "above 400-mph" class; had the first successful twin-boom design; was the first twin-engine "interceptor" fighter; the first American airplane to have flush- or butt-joined external surfaces; the first fighter of its weight; the first to mount its guns ahead of the pilot where they fire straight ahead, rather than in a "cone"; the first to make extensive use of stainless steel; the first to be delivered under its own power to bases overseas; the first fighter to carry and launch torpedoes; and the first fighter to tow gliders.

The versatility credited to the P-38 was a pure by-product, however, rather than designed intent. Lockheed primarily designed a fast, rapid-climbing, hard-hitting, high-altitude fighter. That fact required the ultimate in clean design and great horsepower, which in turn established the plane's other specifications. These in turn have made possible the carrying of bombs and droppable fuel tanks for long-range operation. The high speed made possible the photographic version. In addition, the concentrated fire power was found excellent for ground strafing missions.

Dimensionally, the Lightning (1) was big for a fighter, having a wing span of 52 ft, an over-all length of 37 ft 10 in. and a maximum height from the static ground line to upper tip of the empennage of 9 ft 9 11/16 in. Weight empty is 12,700 lb, and normal useful load is 2,000 lb. However, one specification alternate provides for a gross weight of approximately 18,000 lb.

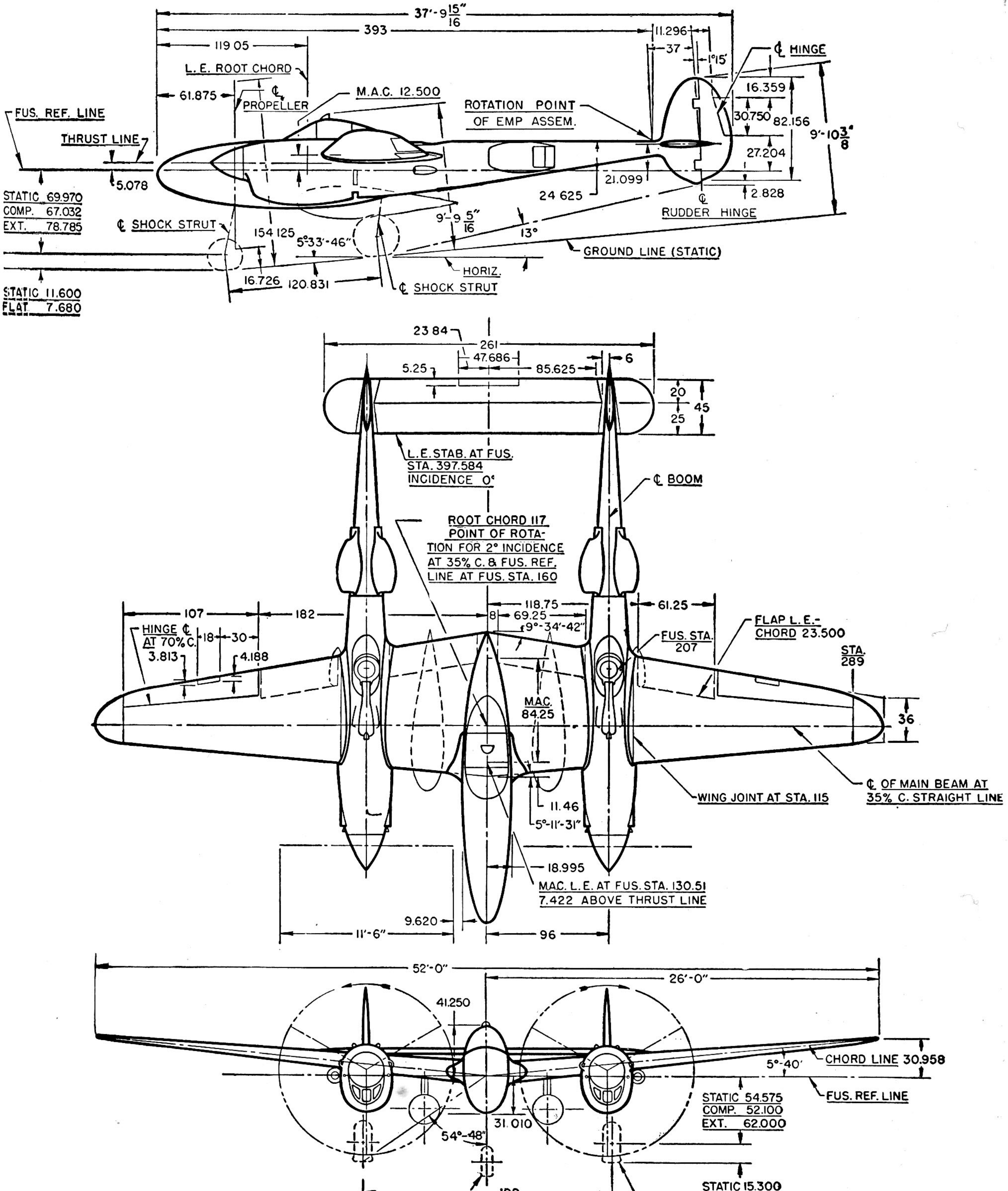


Fig. 1. Three-view silhouette of Lockheed P-38 Lightning fighter. All dimensions on the wing surface are given, neglecting incidence, and are measured horizontally. The dihedral angle is measured at the basic chord plane and does not include incidence. The wing is built with 5°40' dihedral and then rotated about the intersection point of the main beam center line and the wing chord line at the center line of the ship until 2° incidence is obtained. All dimensions referring to empennage vertical surfaces are rotated only 1°15' counterclockwise of vertical and horizontal, respectively.

Every design feature of the P-38, as in most successful airplanes, was originated by necessity. The distinguishing twin booms, for example, were not selected because they would be different. Neither was the twin-boom design originated by Lockheed. Some previous planes of this design, it is true, had not been too successful, but for reasons other than booms. In the P-38 they evolved as a logical development of engine nacelles made long to house the engine oil cooler, turbosupercharger, Prestone radiators, and landing gear. Because of the greater nacelle length, it was logical to extend them into booms to carry the empennage. Engineeringwise, they add nothing or subtract nothing that could not have been achieved in other ways.

AAF specifications, laid down in 1937, were such that power requirements were greater than could be obtained from any single engine then available. Superior speed, rapid climb, high ceiling, and great fire power were the principal objectives demanded by the Air Forces. To these was added placement of fire power where it would be most effective—ahead of the pilot and below his line of vision to provide unexcelled visibility and a distinct advantage in shooting. The pilot can pick up his target quicker and need not get it at the precise apex of a cone of fire such as is necessary when the guns are mounted in the wings.

The P-38 is credited with speeds above 425 mph. This speed, plus great maneuverability due to new booster-type aileron control, plus added dive control obtained by specially designed wing flaps, resulted in a tremendous combat advantage during the Second World War.

Useful loads of the P-38: crew (1 at 200 lb, including parachute), 200 lb; oil (17 gal at 7.5 lb), 128 lb; oil, trapped in system, 60 lb; fuel trapped in system, 20 lb; equipment, 35.55 lb; gun camera, 2.75 lb; useful load (normal), over 2,000 lb; weight empty, 12,700 lb; gross weight (normal), 15,341 lb; gross weight (first alternate), 16,376 lb; gross weight (second alternate), 18,000 lb (approx.).

Unit weights: wing group (net area 327.5 sq ft) 5.54 lb per sq ft; tail group (net area 127.28 sq ft) 3.28 lb per sq ft; weight of cooling system per normal horsepower (2,200 horsepower), 0.48 lb; weight of lubricating system per gallon of oil (26 gal), 7.47 lb.

Weights (airplane empty): wing group, center section, 958.75 lb; outer panels, 612.84 lb; tips, 14 lb; ailerons, 91.68 lb; flaps, 136.31 lb; total, 1,813.58 lb; tail group, stabilizer and tips, 97.33 lb; elevator, 113.09 lb; fins (two), 52.20 lb; rudders (two), 99.49 lb; boom assembly empennage, 55.10; total, 417.21 lb; body group, fuselage less engine section, 667.39 lb; forward boom, 605.06 lb; aft boom, 181.19 lb; total, 1,453.64 lb; alighting gear, main landing gear, 679 lb; nose landing gear, 206.94 lb; total 885.94 lb; nacelle group, nacelles, 471 lb; total, 471 lb; powerplant group, engines as installed (two), 2,730 lb; accessories, 297.30 lb; controls, 80.80 lb; propellers and spinners (two), 827.32 lb; starting system, 82.30 lb; supercharger system (including intercoolers, 130 lb), 613.52 lb; cooling system, 1,065.10 lb; lubricating system, 194.11 lb; total, 5,890.45 lb; fixed equipment, instruments, 73.22 lb; surface controls, 234.40 lb; hydraulic system, 208.95 lb; electrical, 321.08 lb; communicating (AAF), 161.90 lb; armament provisions, 175.54 lb; anti-icing equipment (defrosting tubes), 1.50 lb; total, 1,262.42 lb.

Fundamental design data: maximum over-all length, 37 ft 9 15/16 in.; maximum height, 9 ft 9 11/16 in.; span, 52 ft; thickness of root chord, 16 per cent; thickness of tip chord, 12 per cent; taper ratio (root chord/tip chord) 3.25:1; length of root chord, 117 in.; length of tip chord, 36 in.; maximum fuselage depth, 72 in.; maximum fuselage width, 38 in.; load factor (ultimate), 117.7; design gross weight, 15,500 lb.

The main landing gear is a retractable, single oleo-pneumatic shock-strut type with 36-in. wheel and brake assembly and hydraulic control system. Shock-strut travel is 10 in. The nose gear is a similar type with half-type wheel fork, 27-in. wheel assembly, and shock-strut travel of 12 in.

Bristol Beaufighter

An all-metal mid-wing monoplane, Britain's Beaufighter was used as a two-seat long-range fighter or fighter bomber for day or night operations. Special equipment was installed when these aircraft were operated by the Coastal Command, and a number also acted as torpedo carriers (1).

The main wing, of light-alloy stressed skin, two-spar construction, is made up of a center section and two outer wing panels with detachable wing tips. The center section forms the basic structure of the aircraft, for not only are the outer wing panels attached directly to it but also the front and rear fuselage sections, landing gear units, and engine nacelles (2).

The ailerons are light-alloy, fabric- or metal-covered structures. They are inset and of the Frise type, with both aerodynamic and mass balance. There is an adjustable tab on the left aileron and a trim tab on the right one. Hydraulically operated all-metal split flaps extend between the inner ends of the ailerons and the sides of the fuselage.

The fuselage is a semimonocoque structure with closely spaced alclad formers of lipped channel or Z section, extruded angle-section stringers, and an alclad skin. There is a reinforced crash frame immediately behind the pilot's cockpit and others at the joint midway between the rear cockpit and the tail. Otherwise the formers are mainly of light construction. Keel members along the fuselage bottom carry the concentrated loads from the 20-mm guns.

The landing gear consists of two retractable units and a retractable tail wheel. Each unit is composed of two oleo-pneumatic shock-absorber legs, in the form of a frame, with two inclined drag struts, and a single central hydraulic retracting jack. Medium-pressure tires with pneumatically operated brakes are fitted.

The engines attach to the center wing by steel tube mountings and are enclosed in long-chord cowlings with controllable air flaps.

The fuel supply is carried in four tanks, two in the center wing and one in each outer section. Long-range tanks may be fitted. The oil coolers are mounted in ducts in the leading edges of the outer wings.

The pilot's cockpit, in the extreme nose of the fuselage, is entered through a hatch in the floor (also used as the pilot's main emergency exit) (3), mounted on trunnions at its mid-point so that when open it forms a windbreak for the pilot as he leaves by parachute.

Underhatches cannot be used when a torpedo is carried, entry then being through the hinged roof or hood.

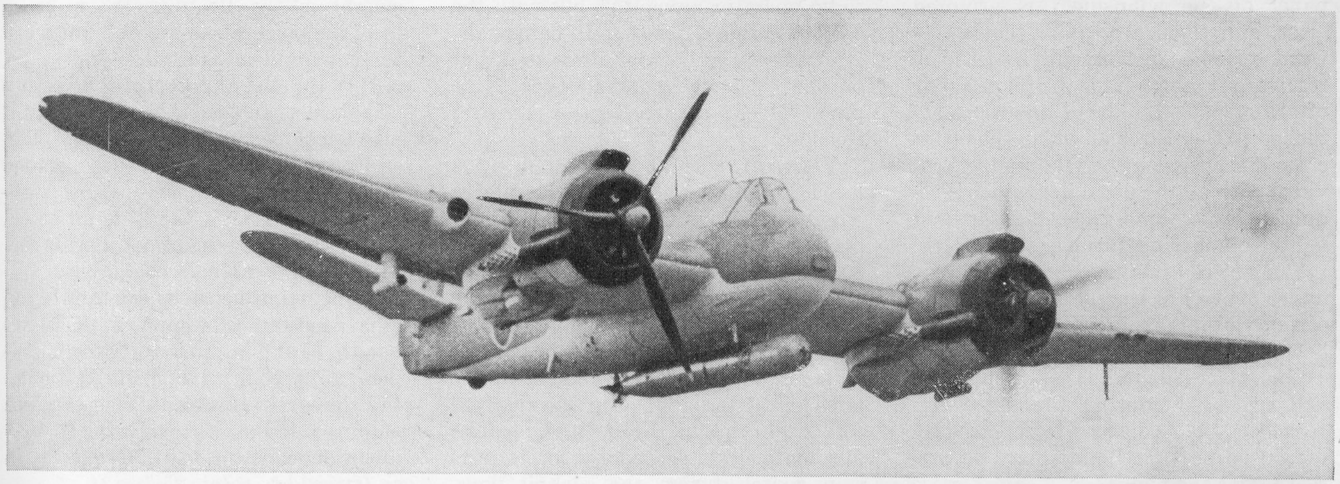


Fig. 1. Torpedo-carrying type of Beaufighter, with 12-deg dihedral tail surfaces, flying with one engine stopped and the propeller feathered. Note the venturi tube beneath the wings for brakes.

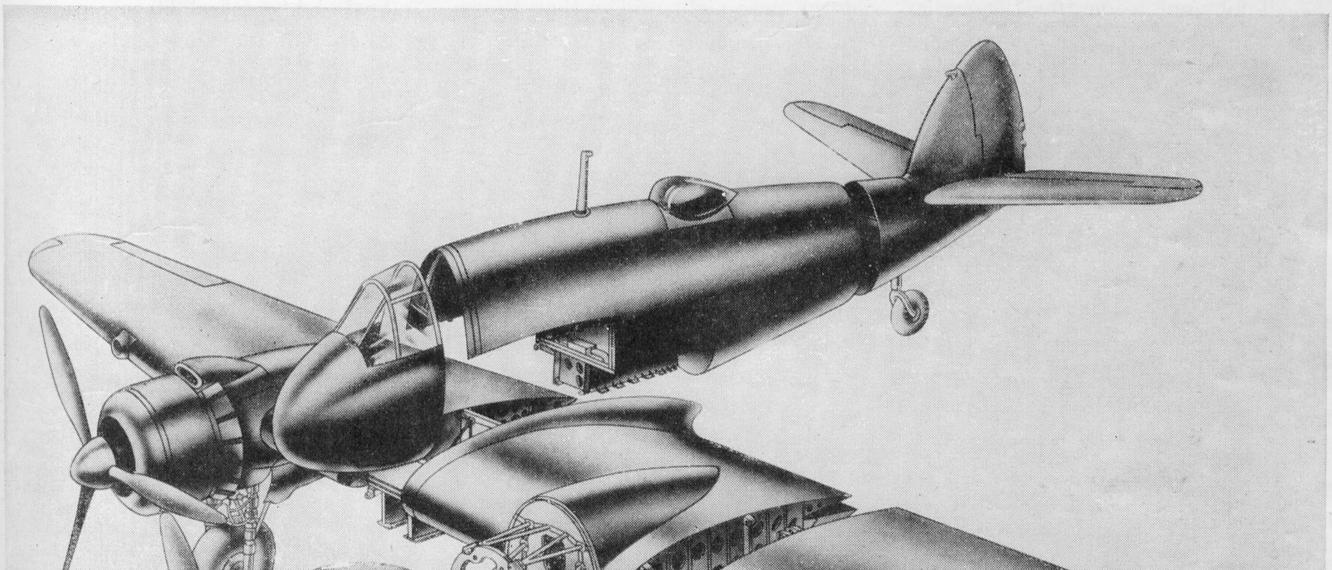


Fig. 2. Exploded view of a Bristol Beaufighter.

A "spectacle" type of handwheel is used for aileron control. The front panel of the windshield is armored glass, and there are armor plates forward of the instrument panel. As rearward protection for the pilot, a pair of armor-plate bulkhead doors are attached to the rear spar where the latter crosses the fuselage. The pilot is provided with all the usual instruments required for a long-range fighter and fighter-bomber operations.

The entire armament of the plane is under control of the pilot. It consists of four 20-mm guns, mounted in the bottom of the fuselage, also four .303-caliber machine guns in the right wing and two .303 guns in the left wing. However, the .303's may be replaced by extra fuel tanks. Bombs may be carried under the wings.

The rear cockpit, which is aft of the trailing edge of the wing, is occupied by a radio operator, on Fighter Command aircraft, who also acts as lookout and as 20-mm gun loader for the earlier type of drum-fed guns. On Coastal Command planes, the occupant is a radio operator-navigator, but with the same additional duties. In fighter aircraft a seat-type parachute is used, but on the Coastal Command type a lap pack gives the navigator greater freedom.

The rear cockpit is entered by a hatch in the floor similar to the pilot's. There is free movement from the rear cockpit to the pilot's seat.

A dinghy, in the rear left-center wing, is manually released by pulling any one of three handles: above front spar on the left side; below observer's emergency door release handle on the left side; externally, atop the fuselage forward of the fin. The dinghy can be automatically released by an immersion switch below the cockpit floor. Marine distress signals are stowed with the dinghy.

Originally designed as a night fighter, this powerfully armed craft brought down more night raiders than the enemy could replace, thus defeating night blitzes. Once the unlucky raider was caught in the Beaufighter's sights, a brief burst from cannon and guns, and the enemy disintegrated.

But the Beaufighter proved such a useful, fast, and reliable aircraft that it was developed further for many other services, including army cooperation work and ground strafing in North Africa and Italy, where its air-cooled engines had the advantage of being able to cope with extreme conditions.

Principal dimensions (aircraft in rigging position) are: span, 57 ft 10 in.; length, 41 ft 4 in.; height (to top of rudder), 15 ft 10 in.; tail span, 20 ft 6 in.; tail dihedral, 12 deg. Wing area, including ailerons, 451 sq ft; tail surface, including elevators, 101.75 sq ft; fin, 13 sq ft; rudder, total, 25.7 sq ft.

Tank capacities are: fuel, center wing tanks (two), 188 gal each; outer tanks (two), 87 gal each; total fuel, 550 gal; oil tanks (two), 18 gal each; air space, 2 gal each; total oil, 36 gal.

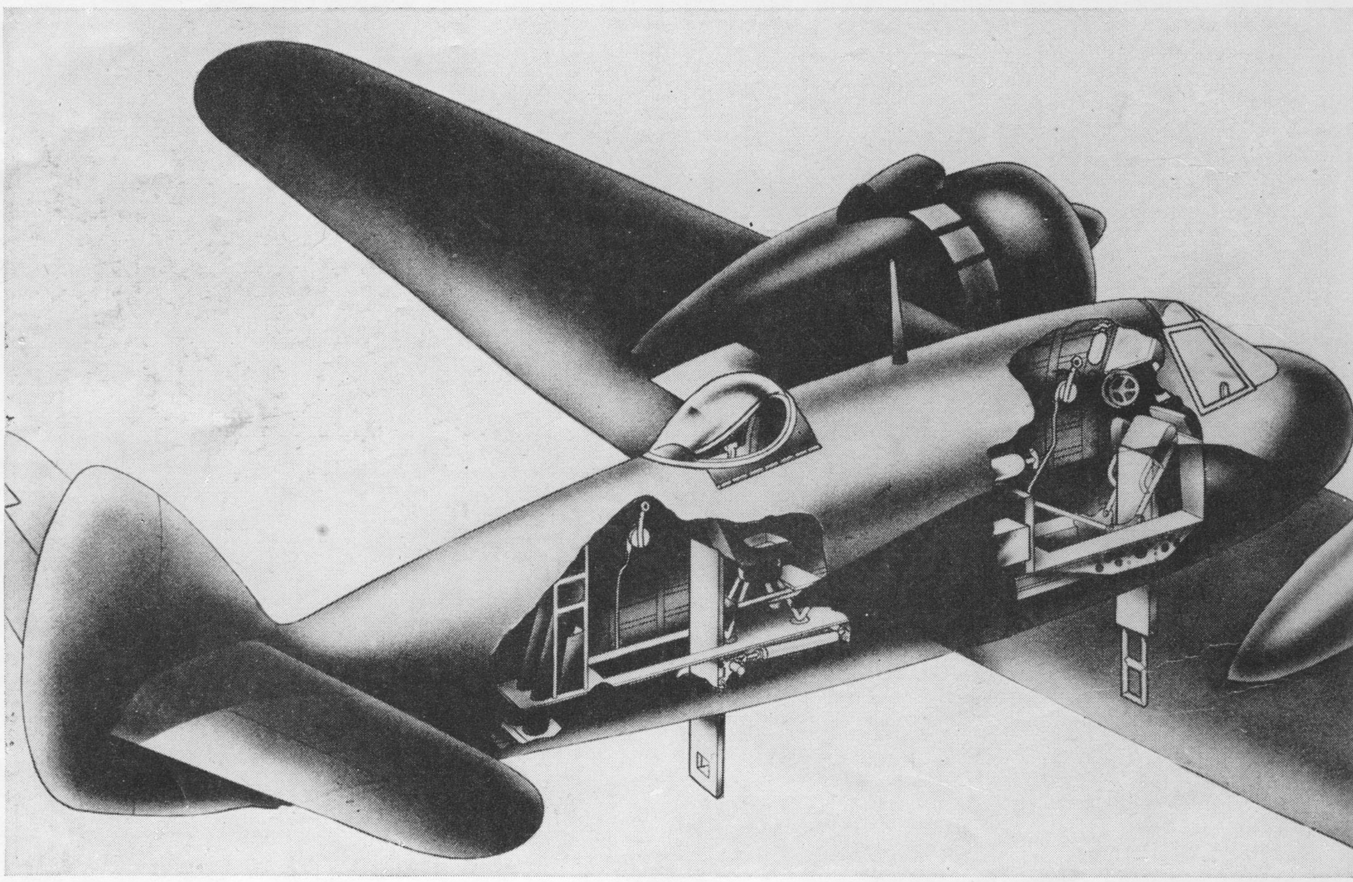


Fig. 3. Emergency exits and equipment. Hydraulically operated exits in the floor give still air for parachute jumps. For crash landings, the pilot has a knockout panel at his right and the observer has a hinged dome. A dinghy for sea landings is in the left wing beneath a square hatch and is operated by a wire release from various points. Automatic fire extinguishers are fitted throughout.

Grumman Mallard Amphibian

The design of the Grumman Mallard Amphibian is of particular interest because it embodies much of the recent rapid progress in hydrodynamics and design technology which has resulted in seaplane and amphibian performance rivaling that of the landplanes of comparable size designed only a few years ago.

In size and cost, the Mallard falls in an uncrowded intermediate class between the newer airliners of the Douglas DC-6, Martin 2-0-2, and Convair Liner 240, and the smaller executive aircraft, including the Beech Bonanza, Navion, and others. The Mallard is the only amphibian licensed by CAA for scheduled airline operation.

Grumman experience has indicated that performance estimates for high-wing types are always somewhat exceeded, while those for low-wing types are frequently disappointing. This was one of the factors which dictated the high-wing design of the Mallard and of the Navy model XJR2F-l (Albatross) whose gross weight is approximately double that of the Mallard.

Power-plant selection finally boiled down to the Pratt & Whitney S3Hl, a direct-drive type with a take-off rating of 600 bhp from sea level to 2,500 ft, and a METO rating of 550 bhp from sea level to 5,000 ft.

This selection provided a total of only 1,200 hp where the estimated power required was 1,400 hp. The economy advantage was evident, but the desired performance could be achieved only by the most careful design.

In the propeller selection the basic requirement was a constant-speed full-feathering type. Top speed and high water clearance with low thrust line were considered. Cruise efficiency was rated second to efficiency in single-engine operation. These factors led to the choice of the Hamilton standard hydromatic, three-bladed type having a diameter of 8 ft 7 in.

A feature of the Mallard's propeller is the lock-pitch control mechanism. With this device the propeller may be hydraulically stopped at any intermediate high-pitch angle, allowing low-speed windmilling in the event of temporary engine malfunctioning.

The first layouts put the propellers ahead of the pilot's cockpit, but it was strongly desired, for visibility and weight considerations, to get the pilots ahead of the propellers. The propellers are 0.4 diameter ahead of the wing leading edge. This is a relatively short nacelle, which resulted in a flow breakdown at the stall. However, it was not a serious problem.

The plane of the propeller lies immediately behind the pilot's bulkhead, which is occupied by lockers in the cabin layout, absorbing the pounding and noise on the skin. The most forward cabin windows are doubly thick, as is the acoustical insulation in this region. The over-all noise level in the cabin is comparable to the DC-3B when cruising at 1,620 rpm with a propeller tip speed of 725 fps. However, with take-off rpm of 2,250, the noise was excessive. Changing from a hard walnut finish on the inside wheel pocket surface to a soft upholstered finish was one of the most successful steps in reducing the noise level to a tolerable degree.

The center of the cabin, which carries

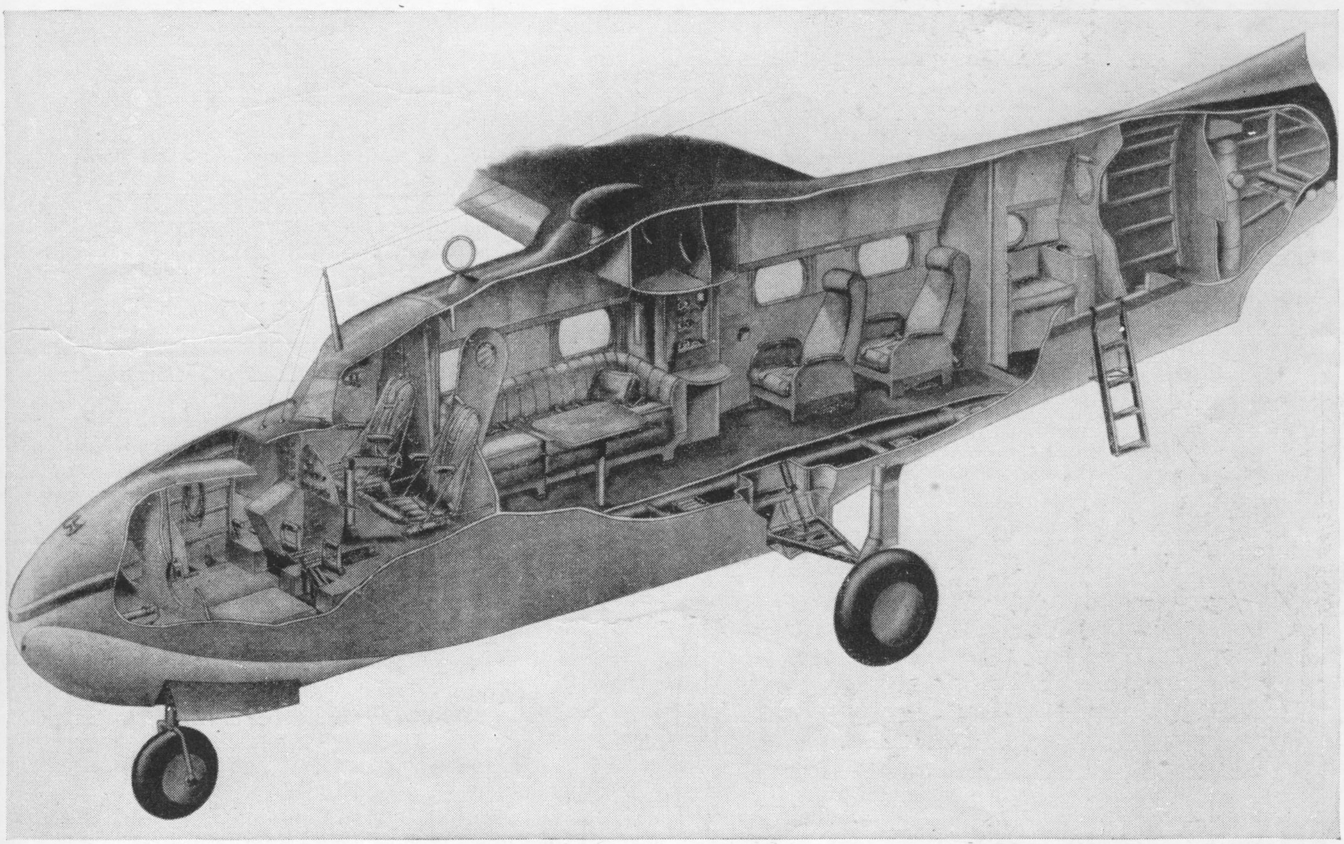


Fig. 1. Cutaway interior view of the Grumman Mallard showing layout of the cockpit and cabin.

the variable load, is directly under the wing beam, so that the Mallard is relatively free from the problems of variable-load disposition. Any number of passengers may be seated at any position without exceeding the c.g. limits of the plane. This is especially advantageous in an amphibian where in the past it has frequently been necessary to change the loading between flight and water operations.

A most elaborate mockup was made, even to upholstery, cushions, and ash trays.

The extremely high tail fin was included again as a consideration to achieve good controllability under single-engine flight, and is so successful in this regard that pilots leisurely go to trim adjustment as the last step after assuming a single-engine configuration. It also is low enough to permit storage in hangars with standard 20-ft doors.

The usual arrangement of the interior (1) provides seats for 10 passengers. The seats and divans are readily removable and interchangeable. Ventilation is obtained through floor registers and adjustable louvers in the side of the cabin. Structural provisions have been made for an overhead hatch for cargo purposes, large enough to permit lowering one of the plane's own engines, which subsequently could be pushed forward between the wheel pockets.

De Havilland Mosquito

Although the Mosquito's performance made newspaper headlines almost every day during the Second World War from 1942 until its end, the background of unusual design which produced this plane is not common knowledge. Neither are the details of its advanced all-wood construction, which was the culmination of 23 years of de Havilland experience in wooden aircraft. It is of interest to note that during this time all de Havilland designs except one were in wood.

The ideas of Sir Geoffrey de Havilland and C. C. Walker, director and chief engineer, were presented to the British Air Ministry in September, 1939. Their aims were to create a wooden operational aircraft to increase air force strength without further strain on the metal industries and also to sacrifice armament for greater bomber speed.

The design was begun immediately, and in December, 1939, a layout was presented which was never fundamentally changed—a twin-Merlin-engined, two-man-crew wooden bomber without armament, carrying a 3,000-lb bomb load and having a 1,500-mile range at fighter speed (1), (2).

In spite of the fact that the company was rapidly expanding production of Tiger Moths and Oxfords for training purposes, once the Mosquito was proposed, production immediately was started on the prototype—The company's ninety-eight design. Only 29 months after the design layout was completed, a full squadron bombed Cologne—on May 30, 1942.

The use of wood and the employment of the woodworking indus-

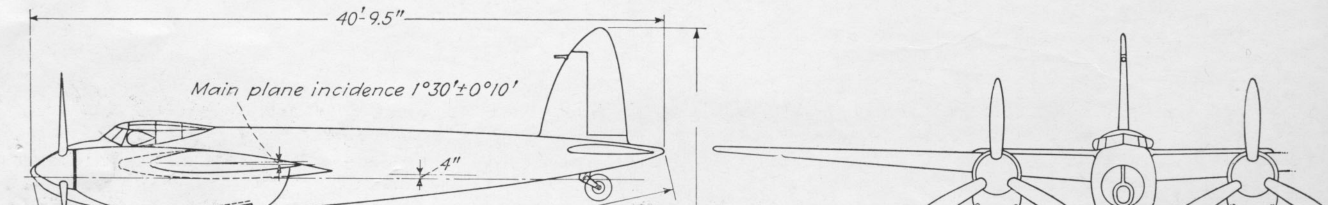


Fig. 1. Three-view drawing of a de Havilland Mosquito.

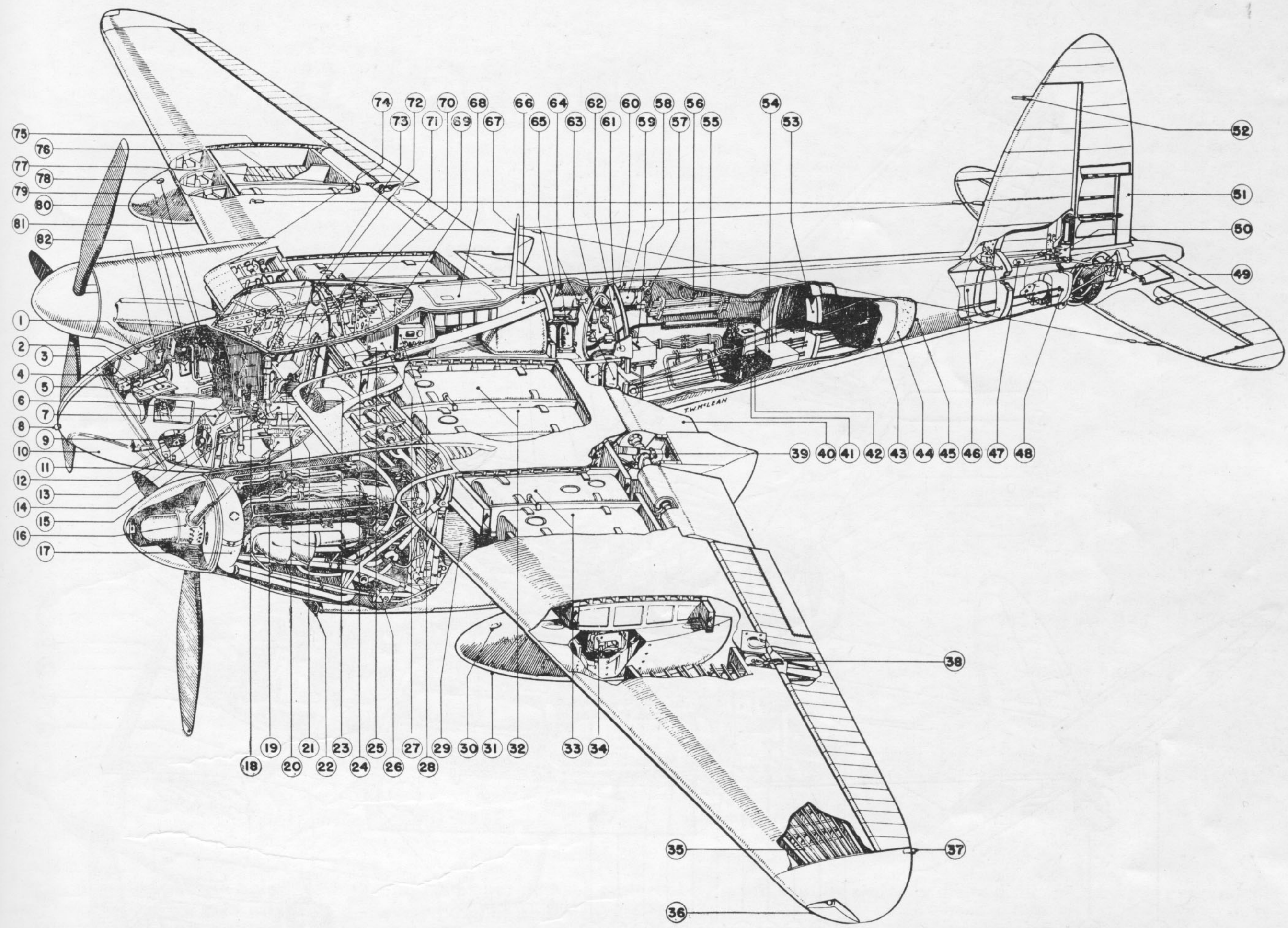


Fig. 2. Upper and lower sectional view of Mosquito: (1) fireman's ax; (2) bombardier's elbow pad; (3) intercommunication; (4) portable oxygen bottle; (5) bombardier's writing pad; (6) pilot's compass; (7) parachute stowage; (8) navigation headlight; (9) bombsight; (10) bombardier's window; (11) impact switch; (12) Plexiglas nose; (13) gravity switch; (14) fire extinguisher; (15) pilot's thigh rests; (16) hydromatic propeller; (17) coolant header tank; (18) pilot's seat; (19) intercommunication; (20) engine controls; (21) elevator trim tab handwheel; (22) carburetor air intake; (23) oil and coolant radiators; (24) pilot's harness; (25) throttle and propeller controls; (26) oil trap; (27) radio transmitter; (28) radio compass; (29) oil tank; (30) dump tank filler cap; (31) dump tank; (32) inboard fuel tanks; (33) outboard fuel tanks; (34) dump fuel tank release gear; (35) stringers; (36) navigation lamp; (37) identification lamp; (38) aileron control; (39) flapjack and crank; (40) flaps; (41) rear camera; (42) stowage for camera-heating cables; (43) plywood inner skin; (44) balsa; (45) plywood outer skin; (46) bulkhead 6; (47) rudder mass balance; (48) bulkhead 7; (49) trim tab; (50) rudder linkage; (51) trim tab; (52) Pitot head; (53) bulkhead 5; (54) camera-mounting boxes; (55) spike pickets; (56) DF loop; (57) lamp; (58) radio; (59) compressed air container; (60) deicing fluid tank; (61) bulkhead 4; (62) ground starter plug; (63) pneumatic-hydraulic panel; (64) oxygen bottles; (65) hydraulic tank; (66) long-range oil tank; (67) aerial mast; (68) dinghy stowage; (69) antenna loading unit; (70) pilot's armor; (71) observer's seat; (72) trailing aerial winch; (73) observer's armor; (74) oil and coolant radiators; (75) double top skin and stringers; (76) single underskin and stringers; (77) aileron tab control; (78) observer's demand oxygen regulator; (79) instrument panel; (80) camera temperature gauge box; (81) camera leads stowage; (82) inspection lamp stowage;

tries contributed largely to the speed with which the Mosquito was put into production. It was built in three types: bomber, fighter, and photoreconnaissance.

De Havilland's long experience in the building of all-wood airplanes has been fully utilized. The chief feature of the design is the balsa-plywood sandwich principle used in building the fuselage and other structural wood parts. Prior to the war this fabrication was successfully applied to de Havilland Albatross four-engine transports.

Wood construction has many advantages according to Mosquito designers. It materially reduced the time required to design and produce the prototype, compared with a metal aircraft. Wood design is one of the quickest methods yet devised to produce a monocoque-type unit, and by using split fuselage construction, the craft is one of the easiest in which to instal equipment. It utilizes the skilled labor of the woodworking trades, which were greatly curtailed by the war.

Structurally, the plane also has many advantages. Because of the comparatively low skin stresses and light weight of the wood, it is possible to produce a fuselage that offers more resistance to buckling than a metal one of the same weight per square foot. The system of molding fuselages

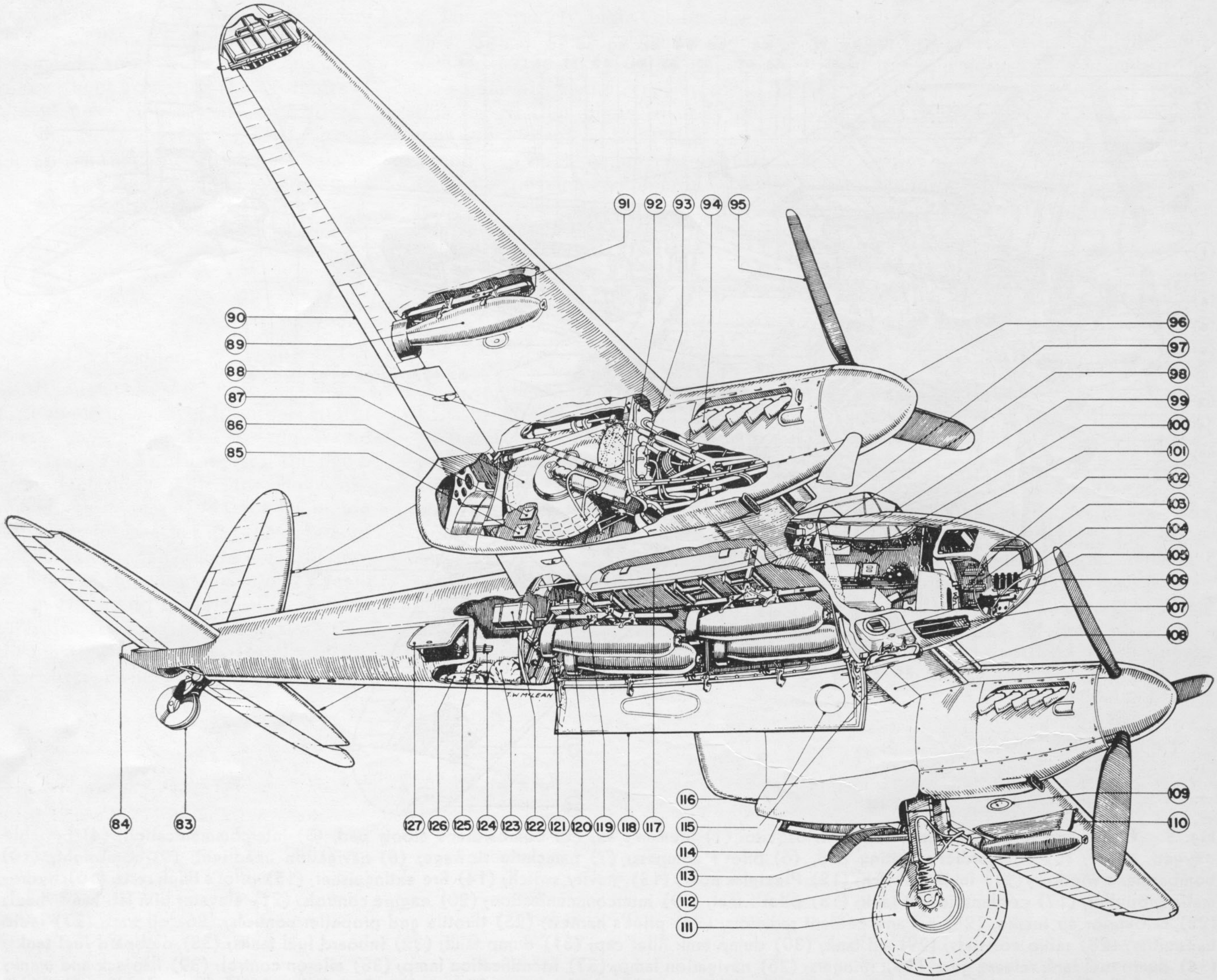


Fig. 2. (*Continued*) **(83) tail-wheel stowage; (84) navigation light; (85) stowage picketing eyes; (86) stowage, landing gear locking cap; (87) landing gear retracted; (88) landing gear jack; (89) 500-lb bomb; (90) aileron trim tab; (91) universal bomb carrier; (92) fire wall; (93) fire extinguisher; (94) stub exhaust; (95) propeller; (96) spinner; (97) cockpit canopy; (98) radio remote-control boxes; (99) pilot's pouch; (100) pilot's demand oxygen regulator; (101) dimmer switches; (102) signal cartridges; (103) fire extinguisher; (104) thermos bottles; (105) glycol spray; (106) tail driftsight; (107) ladder stowage; (108) radiator flap; (109) landing light; (110) wing bond fairing; (111) landing wheel; (112) brake hose; (113) mud guard; (114) landing gear doors; (115) entrance door; (116) camera window; (117) center fuel tank; (118) bomb-bay doors; (119) bomb carriers; (120) bomb winch; (121) bomb-bay door jack; (122) ration container; (123) engine covers, sleeping bags, etc.; (124) locking controls, stowage; (125) signal strips; (126) emergency tool kit; (127) rear entry door.**

makes them remarkably free from "waviness." When finished, they are fabric-covered.

However, an all-wood airplane must also be perfectly drained (3). Even parts not exposed may absorb moisture condensed within, so that every point of possible collection must be included. Three types of drainage openings are shown in (4).

The one-piece full cantilever wing also is of all-wood construction. It is formed on two full-length box-type wood spars. The top skin is made from two 0.25-in. plywood skins separated by Douglas fir stringers. Also of wood construction are the tail plane, fin, and flaps.

The engines and main landing wheels are mounted on the wings and completely streamlined by sheet-metal nacelles and folding landing gear doors. Inside the nacelles there is a metal bulkhead or fire wall attached to the front wing spar. This is secured to the same brackets to which the tubular framework, which supports the engine in front and the main landing gear in the rear, is attached.

Engine coolant and oil radiators are mounted in the leading edge of the wing between the fuselage and each engine nacelle. Cooling air enters through a

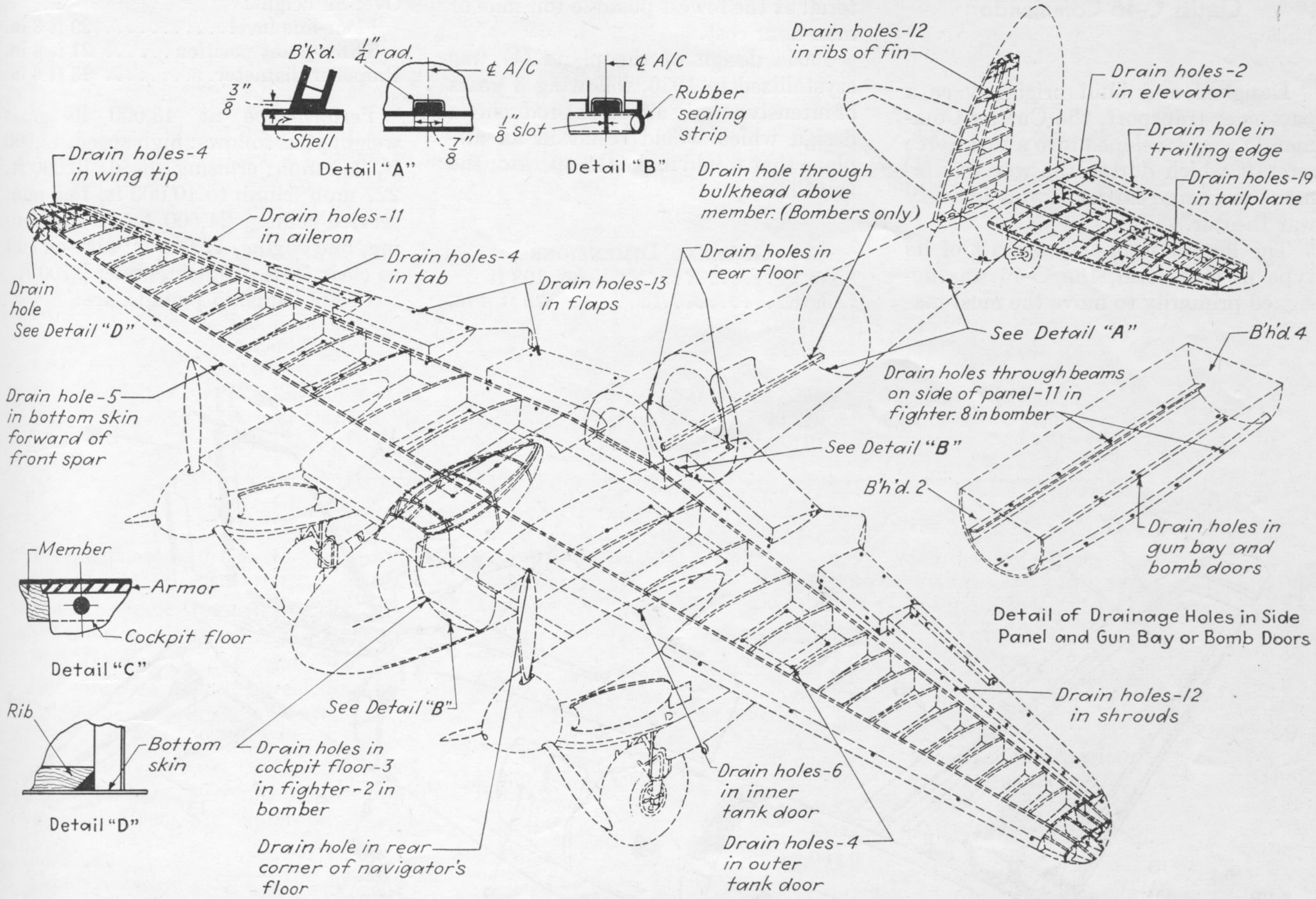


Fig. 3. Location of drain holes. An all-wood airplane, although protected by paint, must be perfectly drained. Even parts not exposed may absorb moisture condensed within, so that every point of possible collection must be included.

fixed opening in the L.E., and air flow is controlled by adjustable flaps on the underside of the wing. Provision is made to deflect a part of the radiator-heated air into the cockpit.

The landing gear is as unique as the rest of this all-wood plane. Here, rubber blocks are provided to cushion landing shocks. This rubber-block design is applied to both main landing and tail wheels.

How unusual the Mosquito design really is can be judged better by a careful analysis of the various units which comprise the aircraft.

Over-all length (maximum) of the Mosquito is 40 ft 9½ in.; height over fin and rudder, 17 ft 5 in.; span, 54 ft 2 in. Net area of wing is 440 sq ft; taper ratio (root chord/tip chord), 3.2:1; length of root chord (25 in. from fuselage center line), 12 ft 3 in.; length of tip chord (300 in. from fuselage center line), 3 ft 10 in. Maximum depth of fuselage is 5 ft 5½ in.; maximum width, 4 ft 5 in. Design gross weight (Canadian handbook), 21,313 lb.

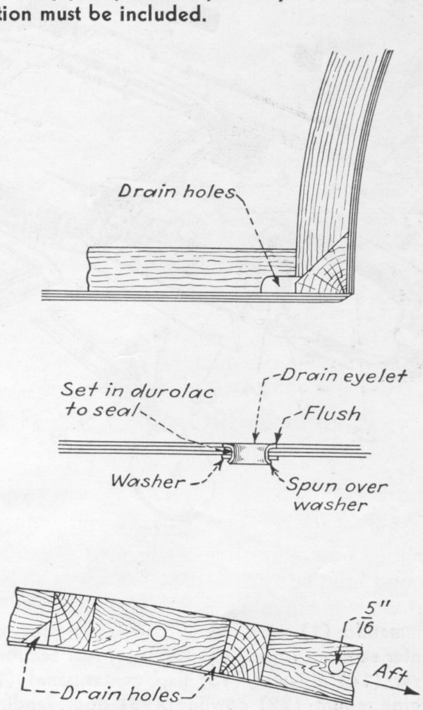


Fig. 4. Types of drainage openings used.

Curtiss C-46 Commando

Designed and built originally as a passenger transport, the Curtiss Commando was developed into a task-force aircraft which during the war was famous as a cargo carrier serving in every war theater.

The largest twin-engine craft of its type in the world, the C-46 was designed primarily to move the most material at the lowest possible ton-mile or man-hour cost.

Basic design of the plane (1) was crystallized in 1936, following 3 years of intensive study aimed at producing a design which would result in an airplane that would make the operator the most money.

General Dimensions

Span	108 ft
Length	76 ft 4 in.
Over-all height:	
Floor-line level	29 ft 8 in.
Three-point position	21 ft 9 in.
Propeller diameter	13 ft 6 in.

Performance at 45,000 lb gross weight is as follows: high speed, 13,000 ft, 265 mph; cruising speed, 10,000 ft, 227 mph; climb to 10,000 ft, 13.5 min; service ceiling, 24,500 ft; service ceiling, one engine, 12,000 ft; take-off run to clear 50-ft obstacle, under 2,700 ft.

Useful loads, in pounds, are:

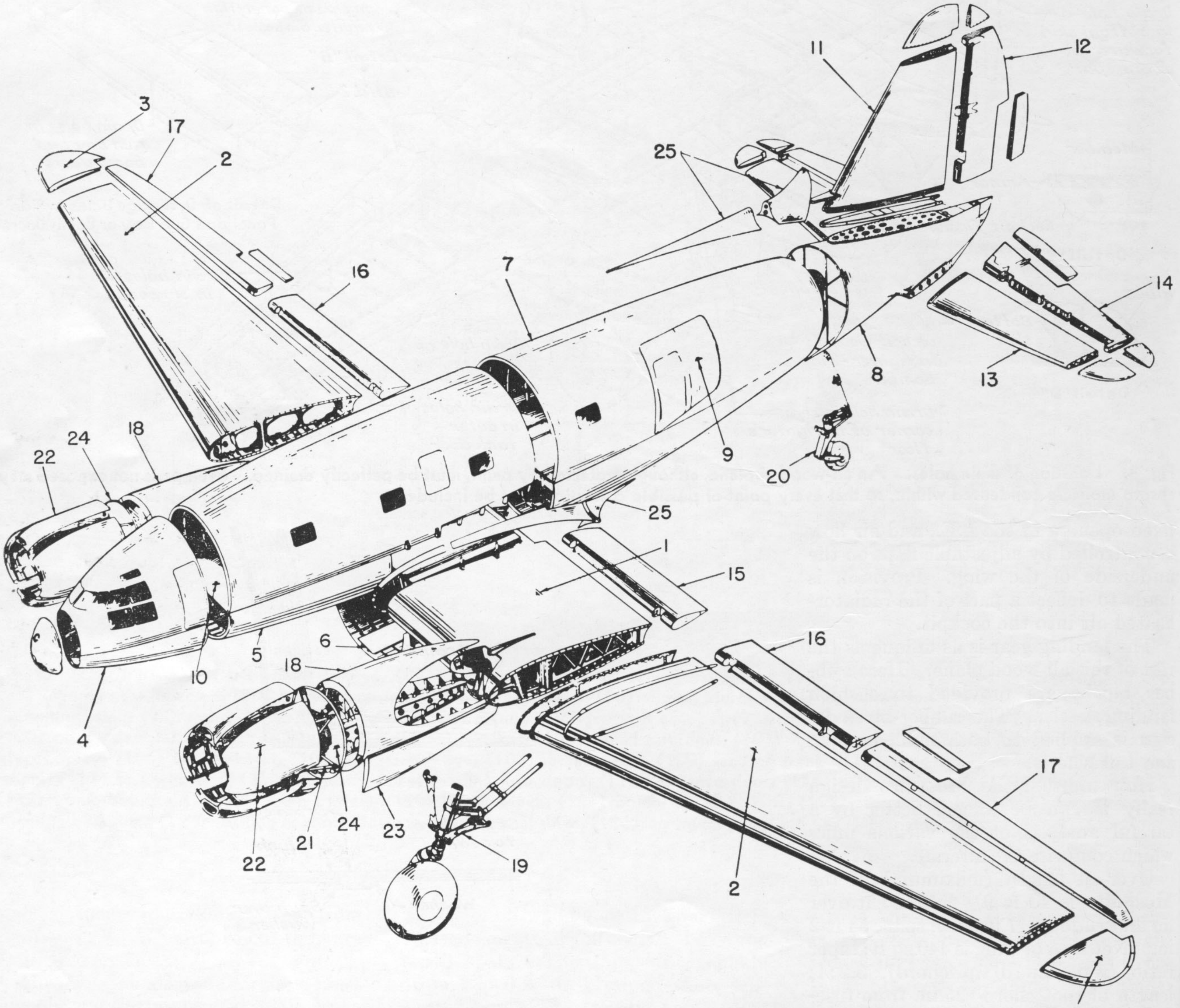


Fig. 1. Curtiss C-46 Commando: (1) wing, center panel; (2) wing, outer panel; (3) wing tip; (4) fuselage, nose section; (5) fuselage, center section; (6) fuselage, center section, lower; (7) fuselage, rear section; (8) fuselage, tail cone; (9) fuselage, cargo door; (10) floor; (11) fin; (12) rudder; (13) stabilizer; (14) elevator; (15) flap, center panel; (16) flap, outer panel; (17) aileron; (18) nacelle; (19) main landing gear; (20) tail wheel; (21) engine mount; (22) cowling; (23) door, landing gear; (24) fire wall; (25) fairing.

	Cargo	Troop transport	Hospital	Long range
Crew	600	600	600	600
Fuel, in addition to normal 1,400 gal:				
488 gal	2,928	2,928	2,928	2,928
570 gal	......	......	......	3,420
342 gal	.....	......	......	2,052
800 gal	......	......	......	4,800
Oil	725	725	725	1,025
Cargo	10,078	......	2,208	
Troops	......	10,000		
Patients (33)	......	......	5,940	
Attendants (two)	......	......	400	
Total useful load	14,331	14,253	12,801	14,825
Weight empty	30,669	30,848	32,199	34,849
Gross weight	45,000	45,101	45,000	49,674

Balance factors, desired design gross weight c.g. location, 25 to 27 per cent M.A.C.: extreme forward position c.g. permissible in flight, wheels down, aft L.E., M.A.C.—20 per cent M.A.C.; extreme rearward position c.g. permissible in flight, wheels up, aft, L.E., M.A.C.—30 per cent M.A.C.

Weights in pounds of the military version, which vary from the peacetime operating models, are as follows:

Wing group:	
Center section	2,389.2
Wing splice	420.2
Outer panel	2,125.4
Tips	46.2
Ailerons	221.6
Flaps	388.6
Provisions for equipment	516.4
Total	6,108.6
Tail group:	
Stabilizer	278.3
Elevator	267.1
Fin	199.4
Rudder	228.5
Provisions for equipment	8.6
Total	981.9
Fuselage group	4,833.0
Landing gear:	
Main	2,462.2
Tail	442.7
Total	2,904.9
Engine nacelle group:	
Nacelles	1,493.7
Provisions for equipment	44.9
Total	1,538.6
Power-plant group:	
Engines (installed)	4,560.3
Accessories	437.3
Controls	69.5
Propellers	1,287.4
Starting system	104.2
Total	6,458.7
Lubricating system:	
Tanks and protection	48.3
Piping, etc	253.2
Total	301.5
Fuel system:	
Tanks and protection	708.1
Piping, etc	208.5
Total	916.6
Fixed equipment group:	
Instruments	139.7
Surface controls	385.7
Hydraulic system	861.6
Electrical	907.9
Communications	658.5
Furnishings	
Personnel accommodations	657.6
Emergency accommodations	205.8
Provisions for flight	258.3
Air-conditioning equipment	373.1
Anti-icing equipment	509.2
Auxiliary power plant	124.6
Winterization	332.2
Total	5,414.2
Service pickup	25.0
Standard weight empty	29,483.0

PART 3. AIRCRAFT HAVING FOUR OR MORE ENGINES

Northrop B-35 and YB-49

The B-35 heavy bombardment aircraft is a flying wing of the pusher type that has been designed for high-speed, long-range, high-altitude operation.

The bomber is powered by four 28-cylinder Pratt & Whitney model R-4360 dual supercharged engines with four eight-bladed dual rotating Hamilton superhydromatic propellers. The YB-49 is powered by eight TG-180 turbojets providing 32,000 hp (1).

The tricycle landing gear is electrically operated and fully retractable. The nose gear is equipped with a single steerable wheel, and the main gear with dual wheels and brakes.

The conventional control wheel, columns, and rudder pedals are furnished for the pilot and copilot. Rudders and elevons are controlled by conventional cable systems and actuated hydraulically. Trim and landing flaps are electrically operated and controlled.

Armament on the B-35 has been omitted, but dummy fairings have been

installed on the outer wings and crew nacelle to simulate turrets and sighting stations. This airplane can carry a maximum bomb load of 40,000 lb; however, with the installation of auxiliary power plants in two bomb bays and fuel tanks in another, the bomb load is limited to 20,000 lb.

Principal dimensions are: span, 172 ft; length overall, 53 ft 1 in.; height overall, 20 ft.

Wing chord at root, 37 ft 4 in.; chord at tip (theoretical, 86 ft from crew nacelle center line), 9 ft 4 in.; incidence at root, 5.5°; incidence at tip, 1.5°; dihedral (along leading edge), 0°53′; sweepback (any station), 26°57′48″.

Wing area (less elevons and trim flaps), 3,581.88 sq ft; elevons (total), 764 sq ft; trim flaps (including 105.5 sq ft of rudders), 154.12 sq ft; landing flaps, 414.50 sq ft.

The eight fuel tanks hold 5,000 gal.

The distinctive feature of the 100-ton jet-powered YB-49 is the inclusion of "air separators" or vertical fins, contributing additional stability which in the B-35 is supplied by the propellers. AAF says the YB-49 is capable of delivering "more than 30,000 lb of bombs" and has speed in the 500-mph class.

Avro Canada Jetliner

The first turbojet-powered transport to be developed in the Western Hemisphere, the C-102 Jetliner prototype (1) was built by A. V. Roe Canada, Ltd., and attracted considerable interest in the United States.

The Jetliner is a short- to medium-range craft in several interior arrangements seating from 40 to 60 passengers. It is in the 60,000-lb gross weight class having a wing span of 98 ft, 1 in., an over-all length of 82 ft, 9 in., and a wing area of 1,157 sq ft. Cruising speed is above 400 mph.

Four Rolls-Royce Derwent V engines are mounted in pairs in two underslung nacelles which also house the main landing wheels. Each engine is rated at 3,500 lb static thrust at sea level, ICAN conditions.

Control areas of the C-102 are as follows:

Aileron	51.6 sq ft
Wing	251.2 sq ft
Elevator, total	56 sq ft
Fin and dorsal, net	122.6 sq ft
Rudder, total, net	38.6 sq ft
Total dorsal, fin and rudder	161.2 sq ft
Landing flaps, outer wing	105.2 sq ft
Landing flaps, center section	21.6 sq ft
Dive flaps, nacelle (production version)	15.6 sq ft
Total landing flap area, outer wing and center section	126.8 sq ft
Total dive flap area, nacelle and center section	37.2 sq ft

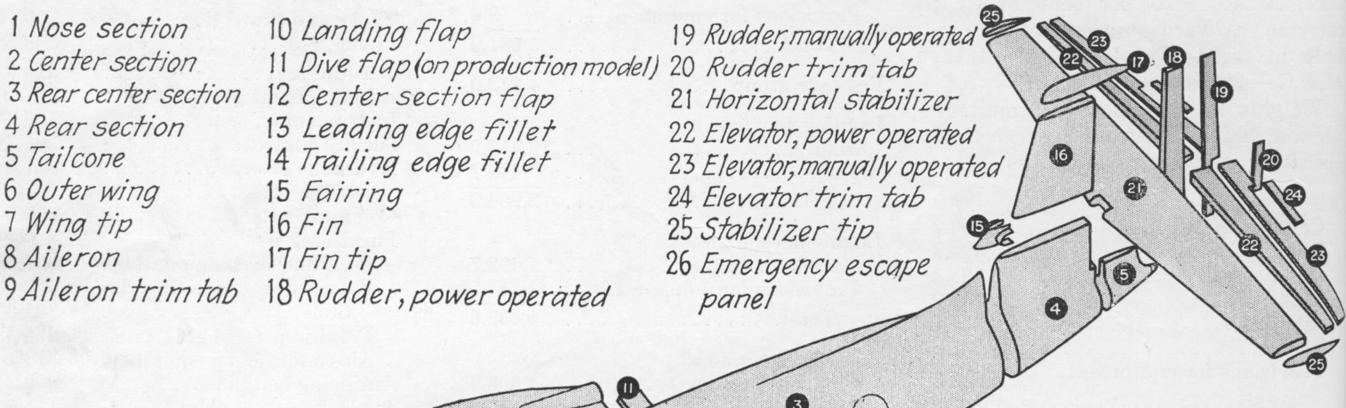


Fig. 1. General design details of the C-102, Avro Canada Jetliner.

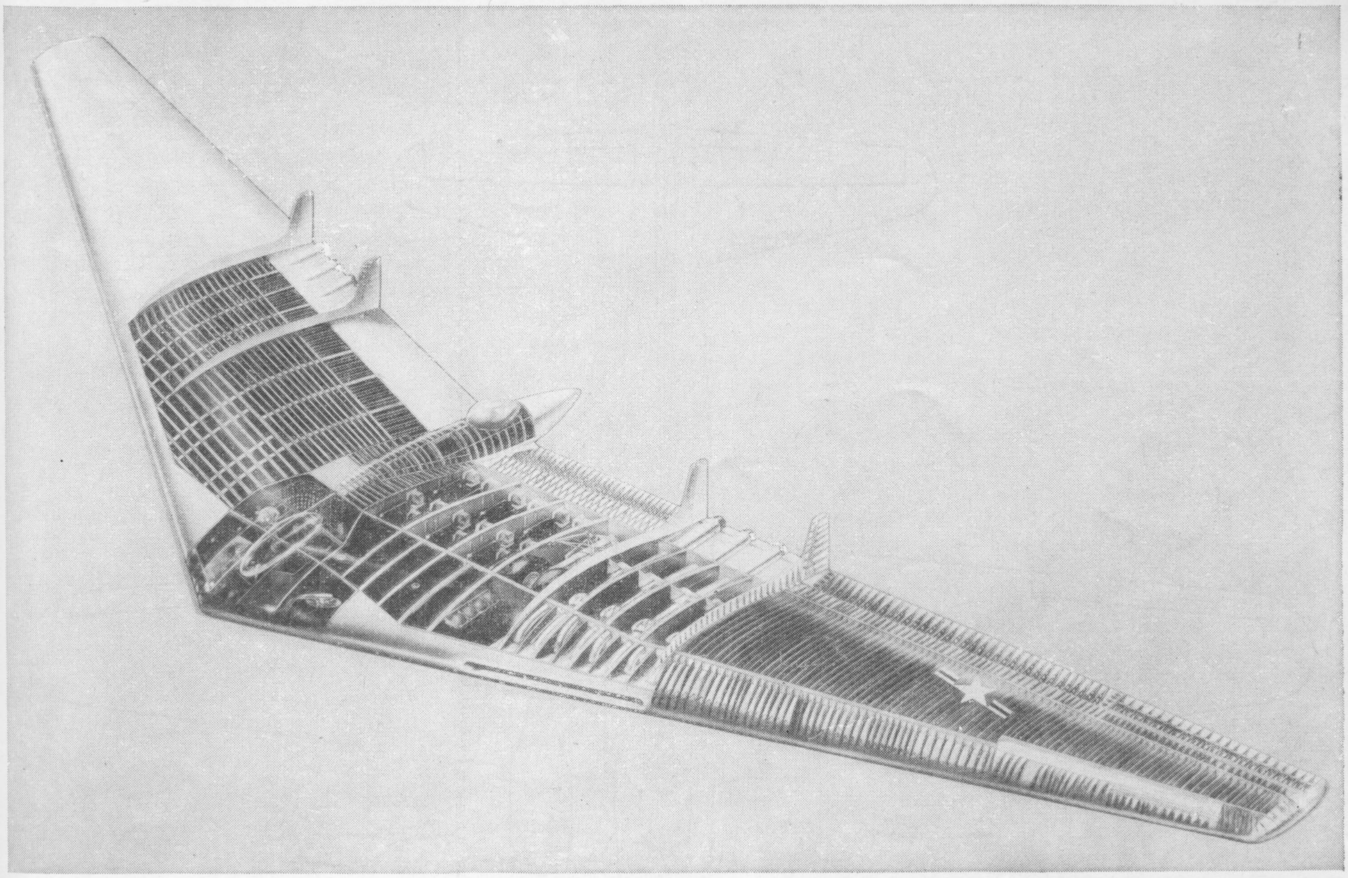


Fig. 1. Phantom drawing of Northrop YB-49 Flying Wing, 100-ton bomber. Fuel tanks are installed in the forward part of the center section each side of the crew nacelle. The main landing gear retracts into wells on the inboard side of the inboard "air separators" which add to the jet bomber's stability. Air intakes for the eight GE-designed, Allison-built TG-180 gas turbines are in the L.E. of the wing between the air separators. Engines develop the equivalent of 32,000 hp.

Boeing B-17

Designed as a battleship of the air, the B-17 (1) was a stable, sturdy platform from which to drop bombs more accurately than any other contemporary heavy bomber of the Second World War.

The operational history of this bomber confirmed that, when the first four-engined heavy bomber was conceived, a third major striking arm—air power—was added to the basic forces of war.

In 1934, Air Corps requests for bids on a "multiengine" bomber that would fly 250 mph, land and stop within 2,000 ft, over a 50-ft barrier, were interpreted by Boeing officials to mean two or more engines, and on that assumption, the four-engine design of the Fortress was based.

In addition to its flying and fighting characteristics, it was conceived by Boeing that the plane would have to be designed to permit manufacture in large quantities, to provide for interchangeability of parts, to service and repair under adverse circumstances of war, and to be sufficiently conservative in design to allow for modification in keeping with ever-changing war conditions.

The rapidity with which the B-17 changed is convincing proof of the wisdom of this early decision, but despite thousands of changes in the several modifications of the plane, the basic design and most of the major specifications remain. The basic structure (2) is one in which skin and stiffening members, such as corrugated sheet, beams, angles, tubes, and rings of formed sheet carry the loads. Structural materials used are 24ST and 24ST alclad, except for engine mounts, fire walls, landing gear, two tubes in each of forward and aft walls of the bomb bay, and other miscellaneous alloy steel fittings.

With an over-all maximum length of 74 ft 8.90 in., height (tail in taxi position) of 19 ft 1 in., and span of 103 ft 9.38 in., the B-17 has a designed gross weight (less bombs) of 38,200 lb, and a recommended take-off weight of about 60,000 lb. Wing area is 1,420 sq ft. Maximum root chord thickness is 41.06 in.; root chord length, 228 in.; tip chord length, 107 in.; taper ratio (root chord/tip chord), 2.43:1; angle of incidence, 3.5 deg; dihedral, 4.5; sweepback (leading edge), 8.25 deg; aspect ratio, 7.58; and mean aerodynamic chord length, 177.5 in.

Design weights of the wing group are as follows: center section, or inner panels, 4,609 lb; outer panels, 942 lb; wing tips, 92 lb; ailerons (counterbalance weights, 24 lb) total 129 lb; flaps, 169 lb.

Tail group weights in pounds are: stabilizer, 445; elevators (counterbalance weights, 14.5 lb) total 177; fin, 257; and rudder (counterbalance weights, 17.3 lb) totals 78.

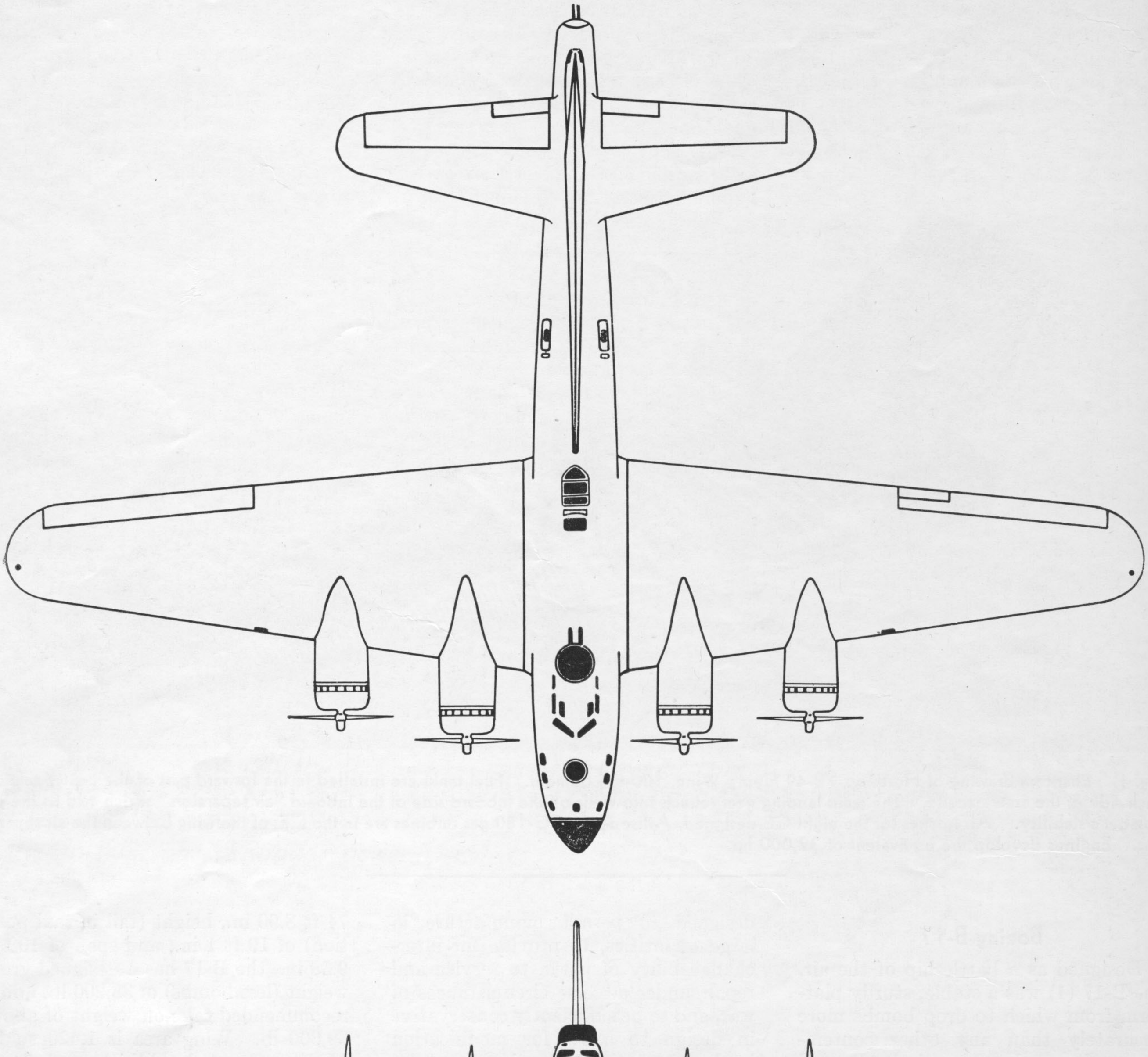


Fig. 1. Three-view drawing of the Boeing B-17 Flying Fortress.

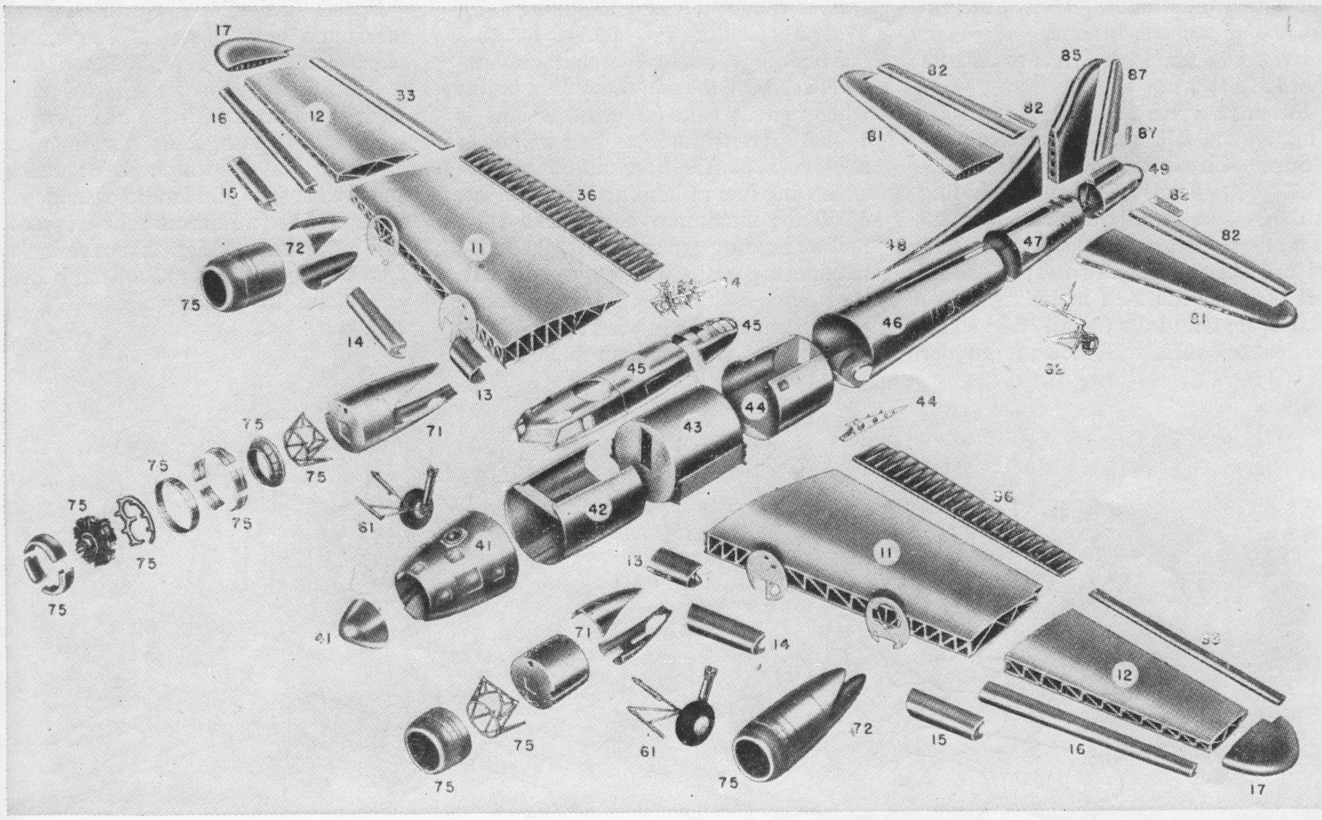


Fig. 2. Exploded view of Boeing B-17 Flying Fortress showing subassembly breakdown.

Body group weight: fuselage, 3,498 lb.

Main landing gear is 2,634 lb, while the tail gear comes to 257 lb.

The four engines total 5,252 lb; accessories come to 1,675 lb; power-plant controls, 109 lb; propellers and spinners, 1,902 lb; starting system, 195 lb; nacelles and cowling, inner, 1,270 lb; outer, 982 lb; lubricating system totals 802 lb; and fuel system, 3,415 lb.

Weights of fixed equipment: instruments, 337 lb; electrical, 1,058 lb; surface controls (including automatic flight equipment), 576 lb; communication, 586 lb; armament (includes armor plate, glass, turrets), 2,766 lb; anti-icing, 294 lb; furnishings, 1,022 lb.

Operation of flaps results in decrease of speed by 9 mph, an increased lift coefficient from 1.6 to 2.10 at 1.2 stalling speed. Gliding angle is increased from 5°39′ to 7°20′ at 1.2 stalling speed.

Flap area, total, is 139.1 sq ft; span (each), 24 ft $4\frac{15}{16}$ in; chord, $34\frac{13}{32}$ in., and movement, 45 ± 2 deg.

Applied gust factors (for design gross weight, 40,260 lb, bomb load 2,060 lb): flaps up, 3.35 positive, 1.67 negative; flaps down, 2.23 positive, .29 negative; (maximum alternate weight 48,726 lb) flaps up, 2.92 positive, 1.20 negative; flaps down, 2.01 positive, .08 negative; (light alternate weight, 34,900 lb) flaps up, 3.70 positive, 2.06 negative; flaps down, 2.40 positive, .52 negative.

Maximum applied landing factors: gross weight (design gross weight less bombs), 38,200 lb; landplane or ground landing, 3.33; gross weight (maximum alternate weight, no reduction for bombs), 48,726; landplane or ground landing, 2.67.

Limited applied high speed (indicated), 305 mph, 125 per cent high speed at sea level. This diving speed is applied to all loading conditions up to and including 48,726 lb alternate weight.

Useful loads, maximum design: crew (six),* 1,200 lb; fuel tanks, 4,404 lb (734 gal fuel); oil tanks, 344 lb (45.9 gal); .50-caliber machine guns (thirteen), 1.43 lb; .50-caliber ammunition, about 1,500 lb; bombs, bomb shackles (two, 2,000 lb), 4,166 lb; residual fuel and oil, 280 lb; total weight with useful load, 48,726 lb.

* In operations, crew totaled 9 and often 10; weight, 2,000 to 2,220 lb, average.

Canadair North Star

The North Star built by Canadair Limited is powered by four Rolls-Royce Merlin 620 engines with two-speed superchargers and is equipped with Hamilton standard hydromatic propellers (1).

It is designed to carry ordnance, cargo, and troops. Accommodations are provided for a crew of five. Except for flight control surfaces, the aircraft is of all-metal construction with approximate over-all dimensions as follows: length, 93 ft 5 in.; height, 27 ft 6 in.; span, 117 ft 6 in.

Chord of wing at root (NACA 23016) is 19 ft 1 in.; chord at tip, 5 ft $10\frac{1}{2}$ in.; incidence at theoretical root, +4°; incidence at theoretical tip, +1°; dihedral (measured at wing reference plane), 7°; sweepback at 30 per cent chord, 1°17′.

Span of horizontal stabilizer is 39 ft

6 in.; maximum chord, 11 ft 3 in.; incidence, 1°; dihedral, none.

Height of fin, 14 ft 3 in.; maximum chord, 12 ft 4 in.

Fuselage width and height are 10 ft 5 in., and 11 ft 6 in., respectively.

Surface areas are: wings (less ailerons), 1,341.6 sq ft; ailerons, including tab, 120.4 sq ft; aileron trim tab, 3.3 sq ft; flaps (total), 241.6 sq ft; horizontal tail surface, 324.9 sq ft; elevators (aft of hinge line and including tabs), 86.5 sq ft; trim tabs (total), 6.84 sq ft; vertical tail surface, 179.3 sq ft; rudder (aft of hinge line and including tab), 47.6 sq ft; rudder tab, 4.75 sq ft.

Maximum take-off weight at sea level is 73,000 lb; minimum permissible wing fuel at take-off gross weight is 14,500 lb; maximum landing weight at sea level is 63,500 lb; minimum permissible wing fuel at landing gross weight, 5,000 lb; maximum permissible wing fuel at landing gross weight, 9,500 lb; maximum permissible gross weight with zero wing fuel (*i.e.*, all weight above this figure must be in wing fuel), 58,500 lb. Weight empty about 44,000 lb.

Speed limitations are as follows: maximum level flight, 265 mph, IAS; maximum glide or dive, 302 mph, IAS; maximum for use of flaps, 154 mph, IAS; maximum with landing gear extended, 180 mph, IAS; maximum for dumping fuel, 220 mph, IAS; stalling speed with flaps and landing gear down, 85 mph, IAS; minimum take-off speed, 118 mph, IAS; design maneuvering at 58,500 lb gross weight, 172 mph IAS; at 63,500 lb gross weight, 174; at 73,000 lb, 180.

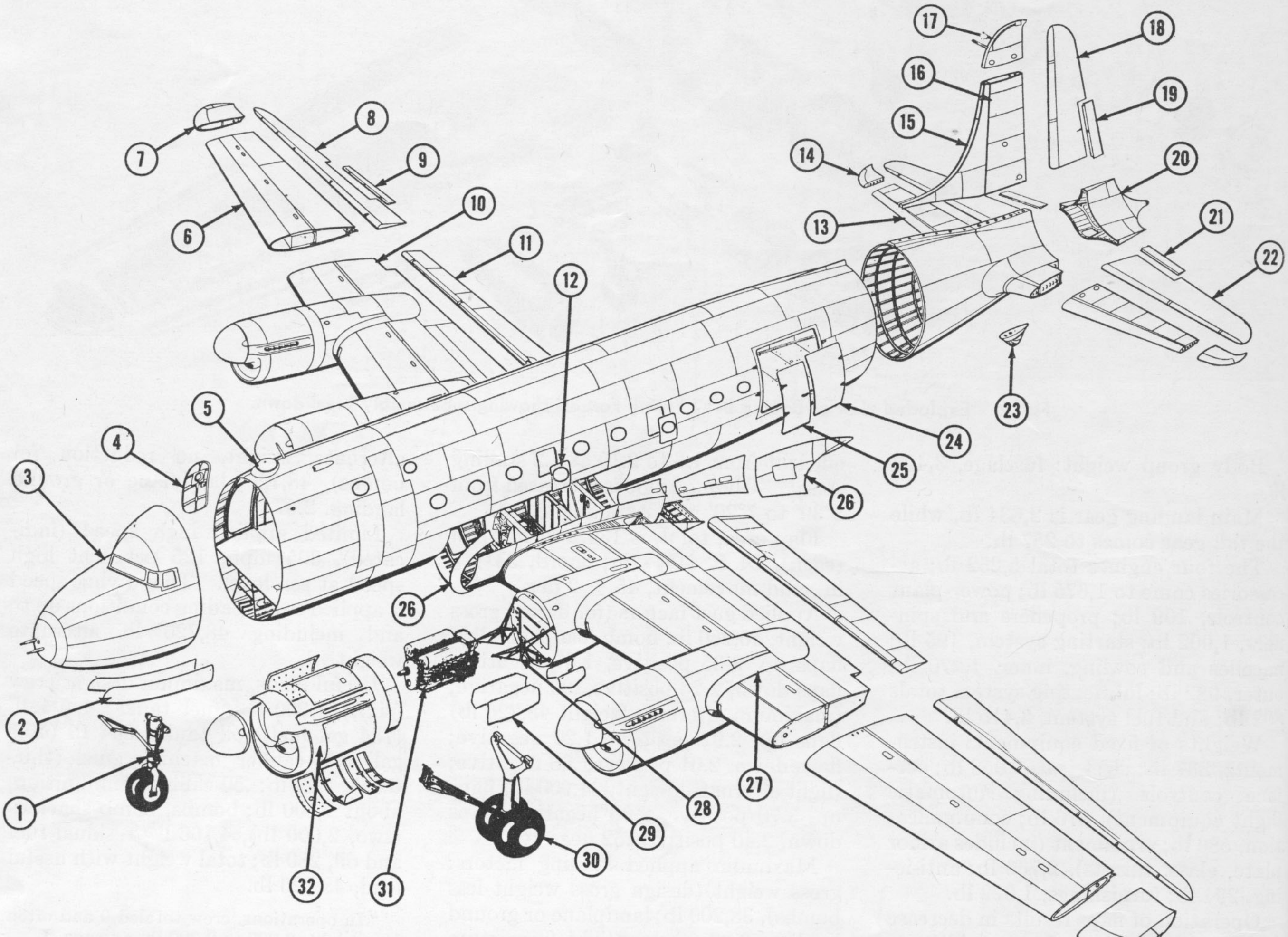


Fig. 1. Exploded view of North Star transport: (1) nose gear; (2) nose-gear doors; (3) fuselage nose section; (4) pilots' entrance door; (5) astrodome; (6) outer wing panel; (7) wing tip; (8) aileron; (9) aileron tab; (10) inner wing panel; (11) flap; (12) emergency exit; (13) horizontal stabilizer; (14) stabilizer tip; (15) fin nose section; (16) fin; (17) fin tip; (18) rudder; (19) tab; (20) tail cone; (21) elevator tab; (22) elevator; (23) tail skid; (24) aft main cargo door; (25) forward cargo door; (26) wing-to-fuselage fairing; (27) nacelle fairing; (28) engine mount; (29) main gear door; (30) main landing gear; (31) engine; (32) cowling.

Consolidated Voltee B-24

In 1939, when the long-range heavy bomber was an accepted type and the backbone of the AAF's flying equipment, specifications called for greater bomb-load capacity, greater speed and range in four-engine design.

The Consolidated B-24 (1, 2) is in no way a radical departure from accepted design practice; instead, it was a particularly successful combination of the

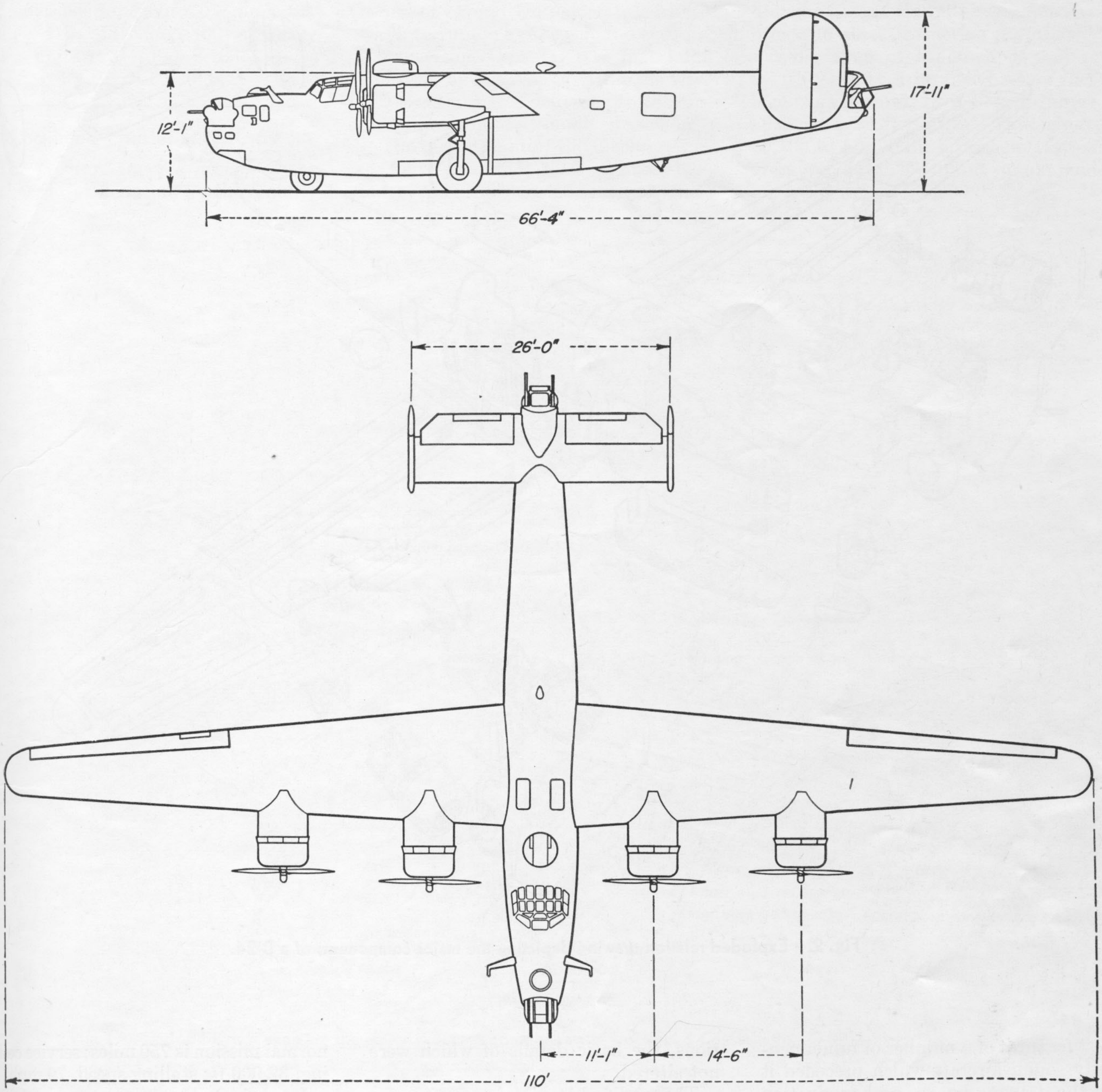


Fig. 1. Three-view drawing of B-24 Liberator, showing major dimensions.

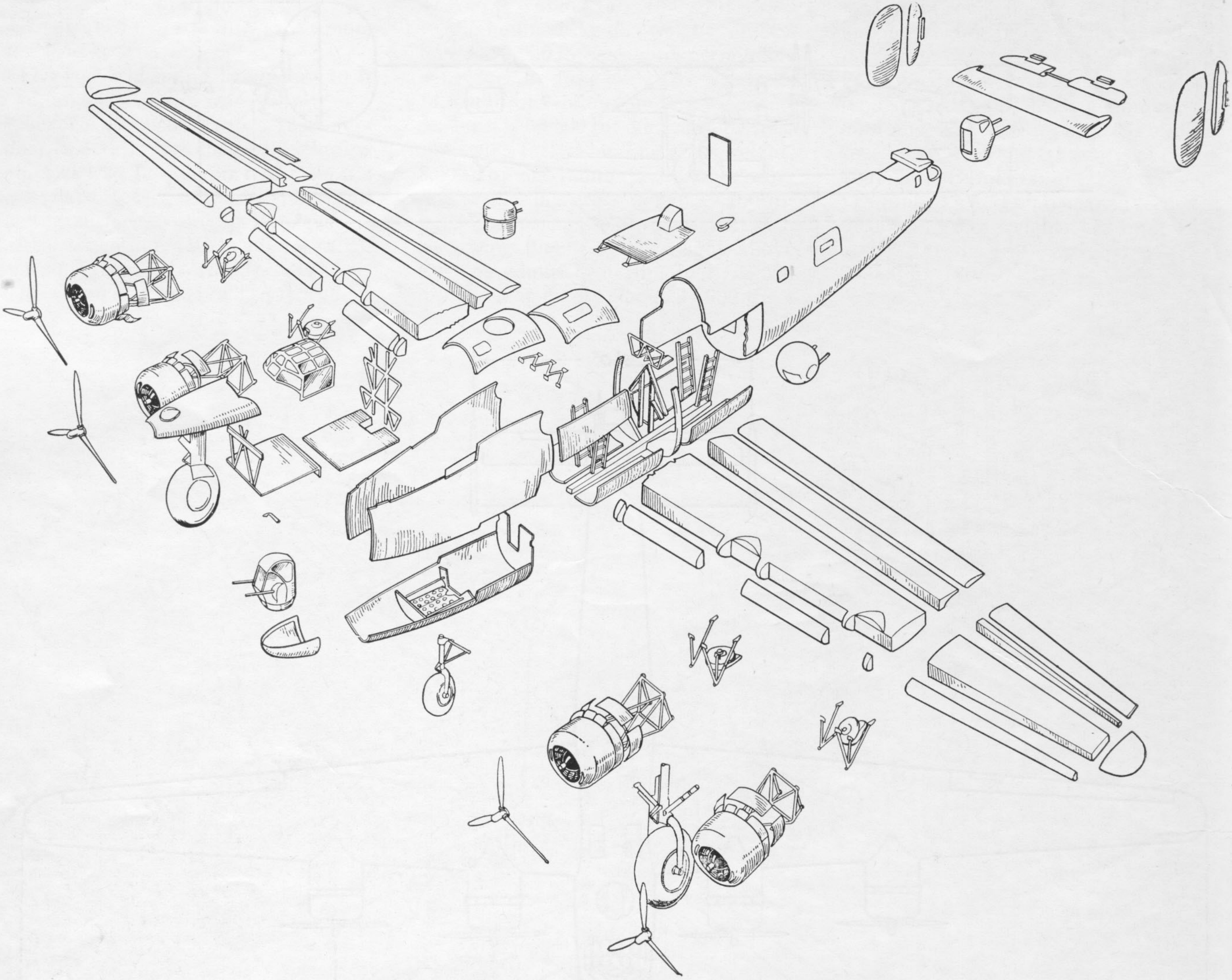


Fig. 2. Exploded relation drawing depicting the major components of a B-24.

best features of a number of fundamentally sound aircraft which preceded it on the drawing boards and production lines of the company.

Although originally designed as a bomber, the Liberator, a four-engined mid-wing monoplane with—initially—twin rudder tail assembly, has had more than 100 modifications and conversions, some 78 of which went into daily use.

The tail assembly later was replaced with a single vertical fin-dorsal assembly, similar to that on the Navy Privateer PB4Y-2, by the AAF. All modifications were made possible by design and performance factors incorporated in the original specifications, the basic details of which were not altered.

The modified Davis wing section was chosen principally for the greater contribution it would make to increased range, through its long-range cruising-speed efficiency. The closed or four-sided modified elliptical fuselage, being actually a beam connecting wing and empennage, would be a deeper, stronger structure and provide greatest space for bomb bays, crew quarters, armament, and operational equipment.

Performance at 56,000 lb gross weight is as follows: high speed at 25,000 ft., military power is more than 294 mph; operating speed at 25,000 ft is more than 230 mph; tactical radius on a normal mission is 750 miles; service ceiling, 32,000 ft; stalling speed, 79 mph.

Loads include: nine-man crew, 2,000 lb; fuel (2,120 gal), 12,718 lb; oil (128 gal), 960 lb; guns and accessories, 1,953 lb; bombs, 2,007. Total useful load, more than 19,638 lb. Weight empty, about 36,652 lb. Lubricating system weights include: tanks and protection, 380 lb; piping, etc., 325 lb, total, 705 lb. Fuel system tanks and protection, 2,248 lb; piping, etc., 280, total, 2,528 lb. Fixed equipment group: instruments, 141 lb; surface controls, 630; hydraulic system, 455; electrical, 1,038; communication, 585; armament provisions, 3,654; personnel accommodations, 163; emergency accommodations,

65; provisions for flight, 707; air conditioning, 112; anti-icing, 460; auxiliary power unit, 123, total 8,133. Gross weight, more than 56,000 lb.

Lockheed Constellation C-69

The program for the design of the Lockheed Constellation for the requirements of several United States airlines was interrupted by the war and the military version C-69 (1) was first built and used by the AAF. After the war, this transport was delivered to the airlines in a somewhat modified version.

The power plant of the C-69 consists of four Wright R-3350 eighteen-cylinder radial air-cooled engines each drawing a 15-ft Hamilton standard hydromatic quick-feathering propeller.

Wing span of the C-69 is 123 ft; length 95 ft $1\frac{3}{16}$ in.; height over fuselage from ground, 18 ft $8\frac{3}{16}$ in.; overall height, 23 ft 8 in. Weight empty 50,100 to 51,400 lb; maximum take-off gross weight 86,250 lb; maximum landing gross weight, 75,000 lb.

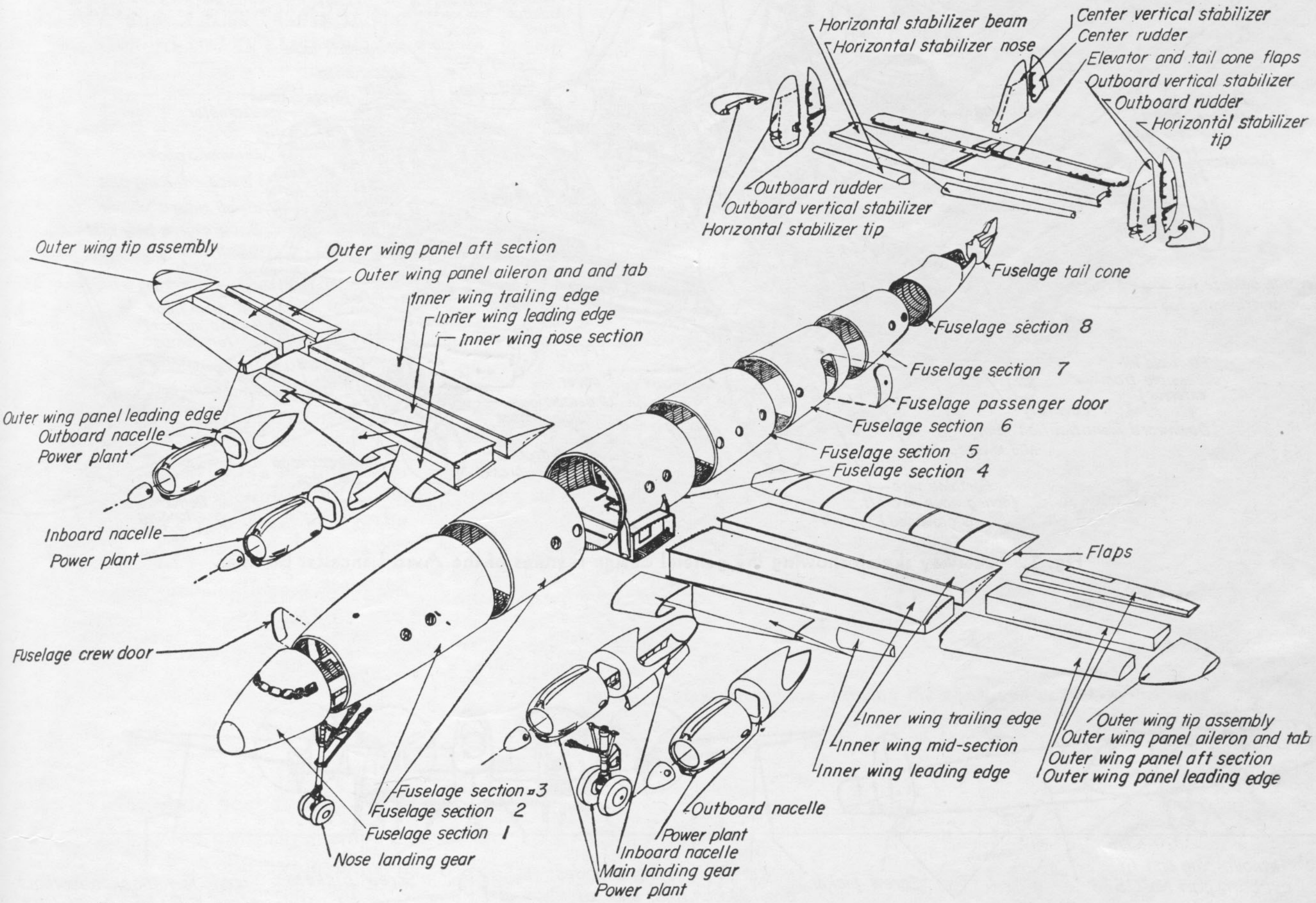


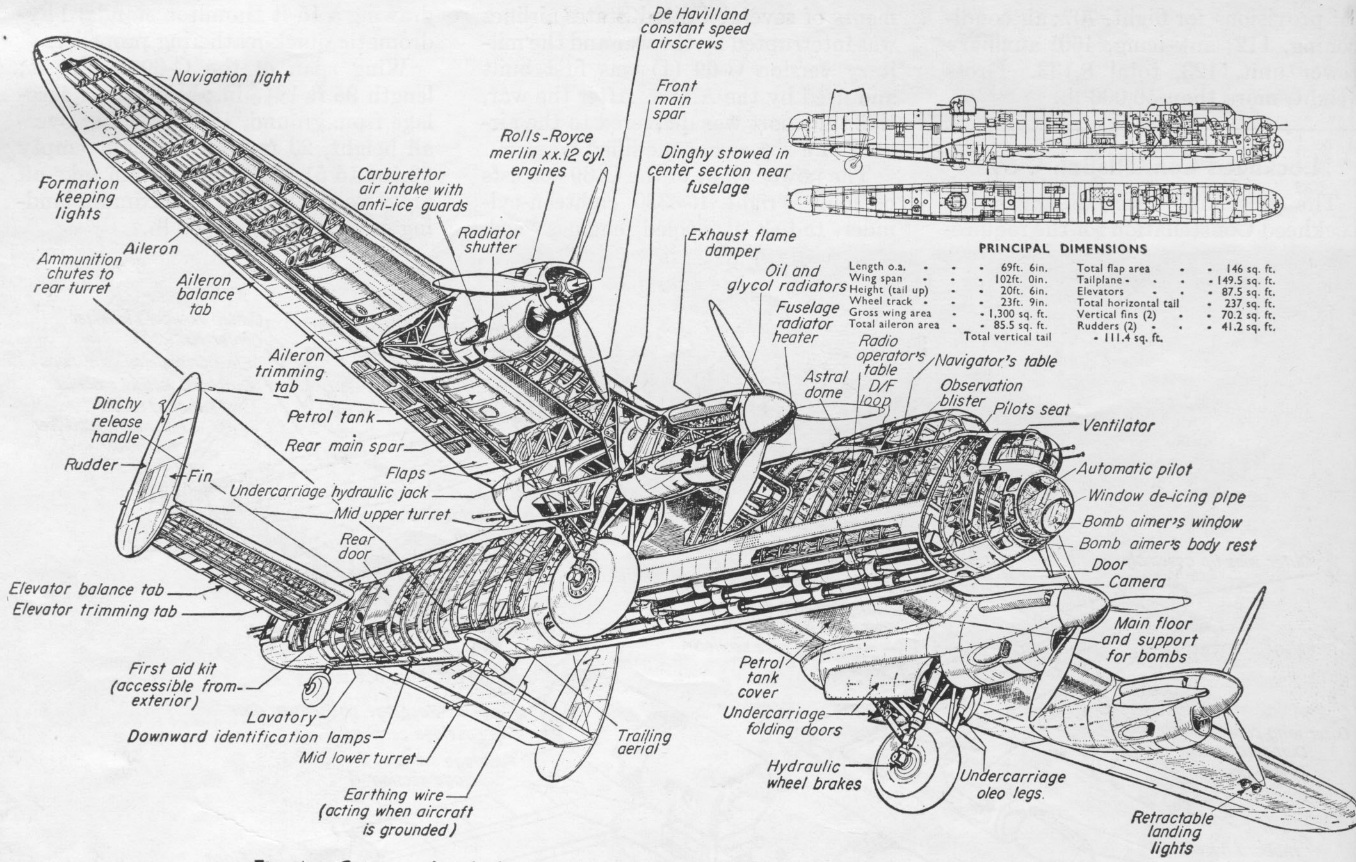
Fig. 1. Exploded view showing the major structural components of Lockheed Constellation C-69 transport.

Avro Lancaster

The Avro Lancaster bomber was produced in four versions as follows: Lancaster I, four Rolls-Royce Merlin XX engines (1); Lancaster II, four Bristol Hercules VI air-cooled radial engines; Lancaster III, same as Mk I but with Packard-built Merlin engines; Lancaster IV (2), same as Mk III but built by Victory Aircraft Ltd., of Canada.

The Lancaster was the most versatile of British heavy bombers. It carries a maximum internal load of 18,000 lb without alteration of the standard bomb bay. For a 1,000-mile range its normal load is 14,000 lb. Modifications of the bomb bay permit carrying both the 12,000- and the 22,000-lb bombs.

Wing span is 102 ft; length, 69 ft 4 in.; height, 20 ft; net wing area, 1205 sq ft; and gross wing area, 1297 sq ft. Wright empty is 37,000 lb; normal weight loaded, 68,000 lb.



PRINCIPAL DIMENSIONS

Length o.a.	69ft. 6in.	Total flap area	146 sq. ft.
Wing span	102ft. 0in.	Tailplane	149.5 sq. ft.
Height (tail up)	20ft. 6in.	Elevators	87.5 sq. ft.
Wheel track	23ft. 9in.	Total horizontal tail	237 sq. ft.
Gross wing area	1,300 sq. ft.	Vertical fins (2)	70.2 sq. ft.
Total aileron area	85.5 sq. ft.	Rudders (2)	41.2 sq. ft.
Total vertical tail	111.4 sq. ft.		

Fig. 1. Cutaway sketch showing the general design features of the Avro Lancaster bomber.

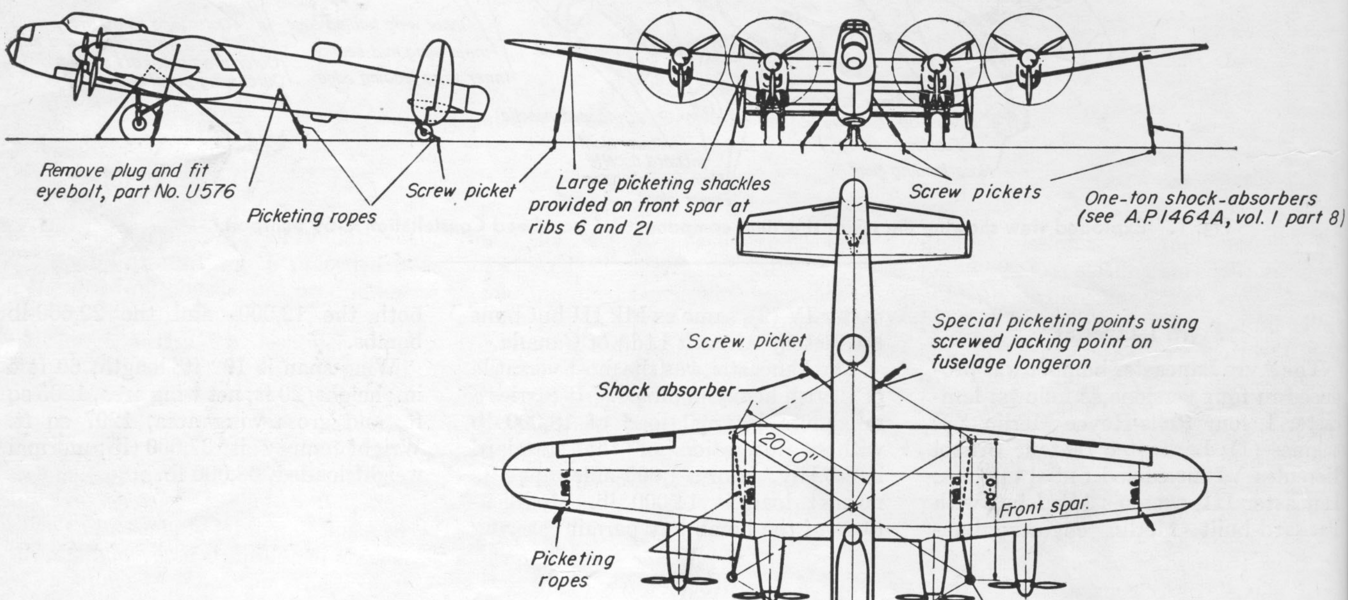


Fig. 2. Three-view drawing of the Lancaster IV built by Victory Aircraft Ltd., of Canada.

Chapter II. WING AND AUXILIARY SURFACE DESIGN

PART 1. SINGLE-ENGINE AIRCRAFT

Ryan Navion

The Navion airfoil is NACA 4415R at the root and NACA 6410R at the tip. Root chord is 7 ft $2\frac{19}{32}$ in.; tip chord, 3 ft 11 in. The wing consists of left and right panels bolted together at a center rib in the fuselage.

No full-span front spar is used, the shear loads being carried by the leading edge and rear spar. The combination rear spar and lower skin is composed of bent-up .032 and .025 24ST alclad sheet reinforced by stiffener angles and spanwise stringers.

Two short spars extending to the landing gear rib act as reinforcing members, one of which, with a shorter beam, supports the main landing gear retracting mechanism (1).*

Total span is 33 ft $4\frac{9}{16}$ in. and total area is 184.34 sq ft, including ailerons, flaps, and 19.89 sq ft covered by the fuselage.

* The numbers in parentheses refer to the illustrations.

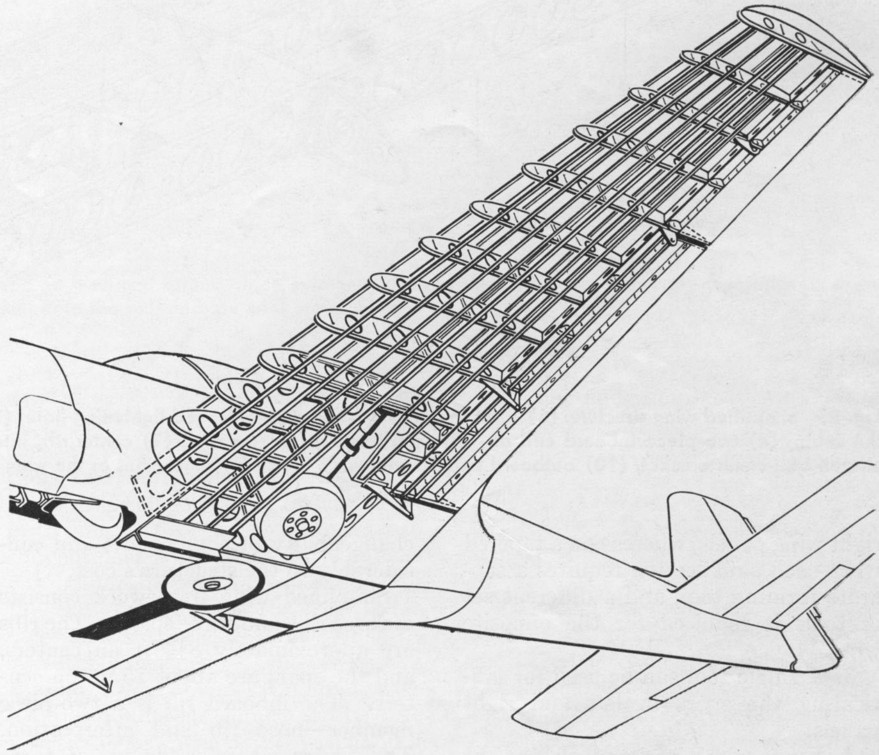


Fig. 1. Cutaway drawing showing the construction of Navion wing.

Republic Seabee

The conventional prototype wing (1) of the Seabee was a good, typical airfoil structure of 24ST—a tapered, full cantilever unit consisting of ribs, spars, and stringers. There were so many interlocking components, all largely inaccessible to automatic machinery, that in the main it had to be assembled almost entirely by hand; hence, it was very costly.

Manufacture of the many detail components was comparatively simple, representing only about 5 per cent of total wing fabrication time; the other 95 per cent was almost all assembly time.

The simplified wing (2) has a rectangular planform, constant-thickness structure, externally braced by a single strut. The reasons underlying the change from tapered to rectangular planform were as follows:

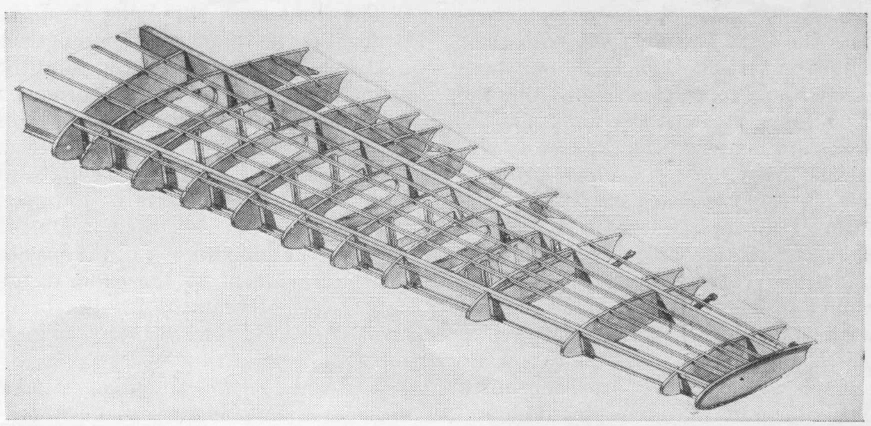


Fig. 1. The conventional type of wing for the Seabee was discarded because 95 per cent of its cost was hand assembly labor.

1. Skin becomes a rectangular sheet, and in bending it to the form of the wing, material losses ordinarily occasioned with a tapered wing are avoided.
2. A single forming tool can be used for all skin sections on both left and

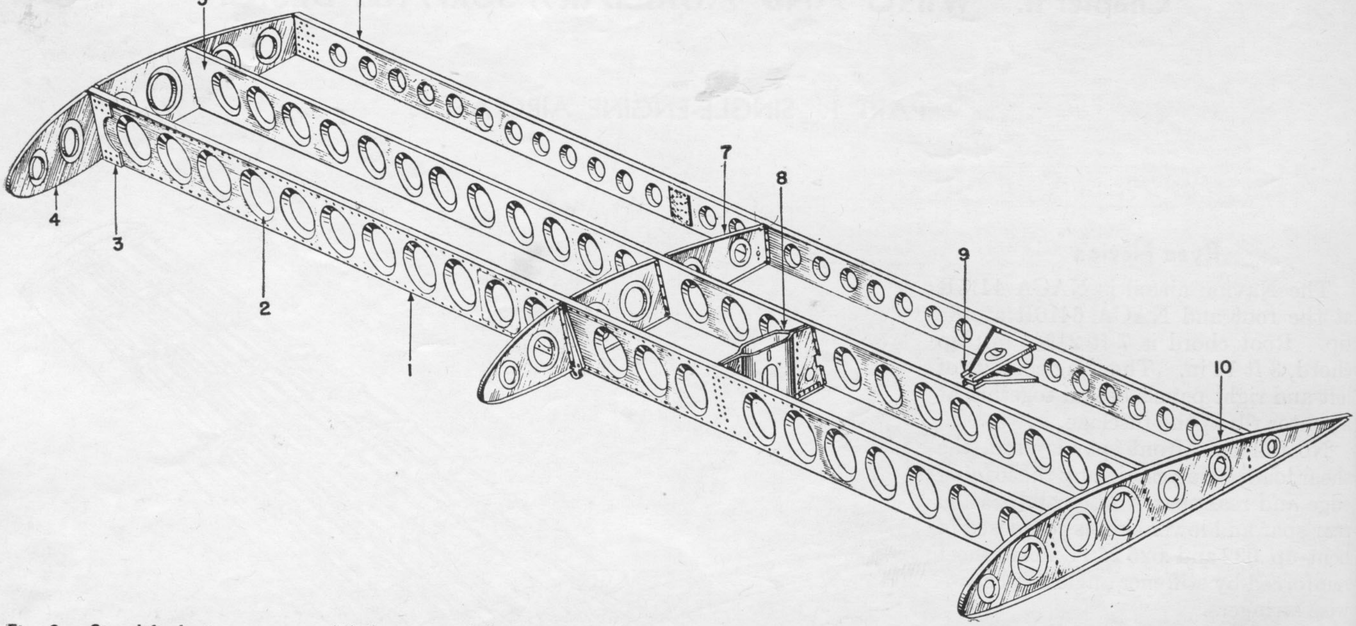


Fig. 2. Simplified wing structure: (1) front spar; (2) 45-deg simple flanged lightening hole; (3) bearing plate for attachment of the front spar to the cabin; (4) two-piece inboard end rib; (5) middle spar; (6) rear spar; (7) center rib, intercostal between spars; (8) wing float socket; (9) aileron bell-crank bracket; (10) outboard end rib with wide flange for attachment of the wing tip.

right wing panels, whereas on a tapered wing each skin section requires a separate forming tool, and a different set of tools is required for the opposite wing.

3. A single tool can be used for fabricating the spars in left and right panels.

4. Exact-width strip stock can be used for the spars, since the flat pattern of the unit is rectangular. This avoids material losses and additional operations required for the tapered spar.

5. Rectangular-planform wing permits the flaps and ailerons, with their hinges and brackets, to be interchangeable left and right, thus eliminating the need for separate tools and material losses attendant on the tapered design.

All these considerations are extremely important in a simplified structure. In contrast, small differences between two assemblies of a conventional design (such as noninterchangeability of left and right skin sections) were not of much consequence, since this condition required only a new set of tools and parts, representing but a negligible portion of the total manufacturing costs which were consumed largely in assembly handwork.

However, in the simplified design, in which handwork has been greatly eliminated, small differences which require additional tools and prevent the interchangeability of components add considerably to the structure's cost.

Simplified wing framework consists of three ribs and three spars. The ribs are approximately 8½ ft on centers, and the spars are about 15 in. on centers. The inboard rib is a two-piece member—nose rib and afterportion. The center rib is made up of three pieces intercostal between spars. The outboard rib is a single member providing for the attachment of wing tip by incorporating a wide flange.

The front spar, supplying about 90 per cent of the wing bending strength, is a 0.64 channel constant throughout the span, having straight flanges turned on a bending brake. Extruded angles of 14ST are nested in top and bottom flanges and extend from the inboard end about three-quarters of the span toward the tip. A simple forging is used on the inboard end of the spar to make attachment to the cabin structure. The attachment for the brace strut is accomplished with another forging at the center rib.

The middle spar—essentially a false spar—is a .032 channel member fabricated in a manner similar to the front spar, but without angle attachments.

The rear spar is a simple .051 channel member having a forging at the inboard end for attachment to the cabin structure.

The wing float supporting structure, consisting of two pressings forming a socket for the float strut, is between the front and middle spars, at about one-quarter the distance from the middle to the tip.

All spars are of R-301W material. Lightening holes have simple 45-deg flanges formed without subsequent heat-treating. Because of severe forming, ribs are fabricated of 24SO and are subsequently heat-treated. Rib lightening holes have deep-drawn flanges.

The wing skin, with beading similar to that on the stabilizer, is R-301W—.032 on inboard half and .025 on the outboard half. Skin sections are pressed on a camel-back draw die, similar to the method used for the stabilizer skin.

In the wing assembly, the skin sections are first spliced on an automatic riveting machine to form a large envelope. Spars are installed progressively, beginning with the front one, and riveting is done on an automatic riveter afforded access to the interior of the envelope from the rear opening.

Rivets are driven through both upper and lower skins and through spar flanges at the same time, in about 8 min. The wing tip is quickly installed on the outboard rib with sheet-metal screws and self-locking sheet-metal nuts.

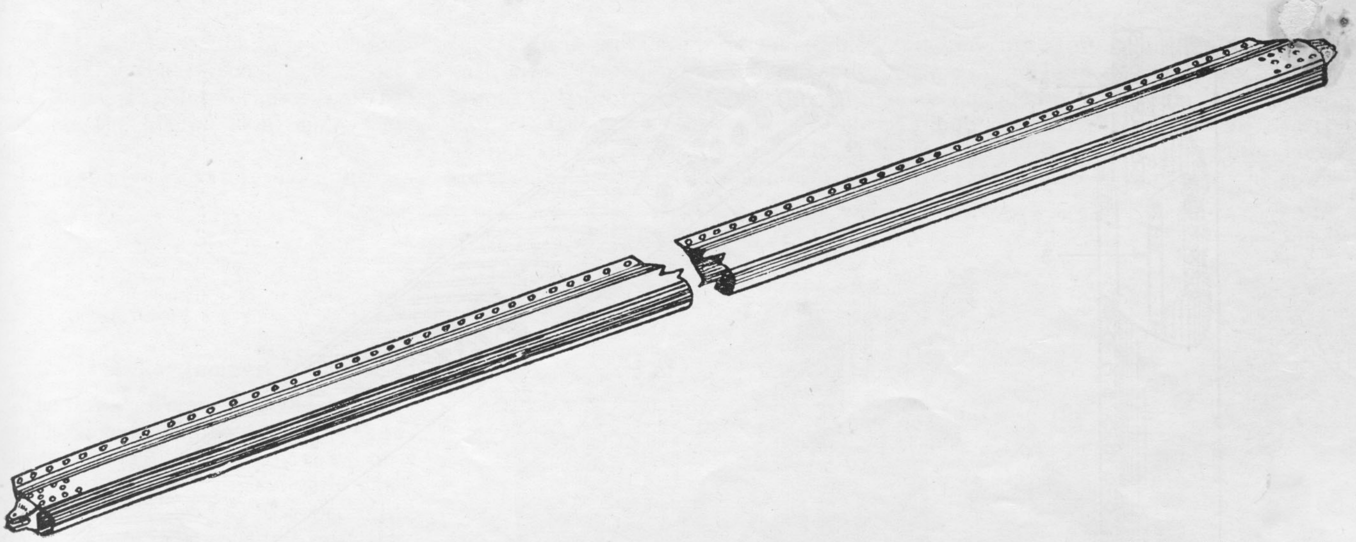


Fig. 3. The wing brace strut is a single sheet turned on itself and joined on an automatic riveting machine along outwardly faced flanges at the T.E. Extruded fittings at the ends serve for attachment to the hull and the wing, respectively.

The external wing brace strut (3) is a single piece of .091 R-301W turned on itself to provide a streamlined section joined at the trailing edge, on an automatic riveter, along outwardly turned flanges. Extruded fittings on each end of the brace strut carry one bolt for attachment to the wing and the hull, respectively.

The wing floats (4) are of R-301W .051 skins formed in a novel manner. Each float is of fully monocoque construction consisting of left and right pressings (clamshells) joined at the plane of symmetry along outwardly turned flanges adaptable for external automatic riveting. The strut (5) connecting the float to the wing slips into a neck section provided in the pressings. The complete float assembly consists of but five parts: two skin sections, two bearing plates for strut bolts, and a drain plug. It can be fabricated in 15 min. This is in sharp contrast to conventional wing floats with numerous bulkheads which are fastened to the skin by reaching through access holes and driving each rivet by hand.

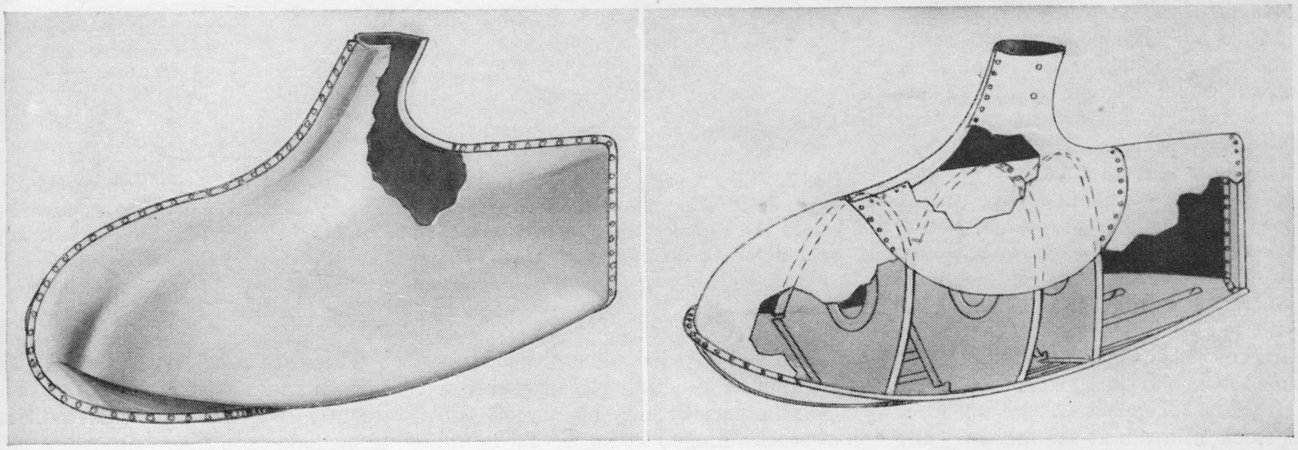
Notable lightness is achieved in this simplified wing design. Complete with flaps and ailerons, brace struts, and miscellaneous fittings, it weighs but 1.45 lb per sq ft—unusual, considering that the average wing loading is 16 lb per sq ft.

Basic make-up comparisons of conventional and simplified wing structures are listed below:

	Conventional	*Simplified*
Parts	114	30
Man-hours	280	10
Rivets	2,627	882
Weight, lb	150	110

The wing, in static test, sustained a load of 115 per cent, and in torsional rigidity was four times greater than CAA requirements. Another unusual characteristic of the wing structure was that no skin ripples or buckles appeared up to 100 per cent of the design load—a condition rarely achieved in a conventional metal wing structure.

These very satisfactory results ob-



(*a*) (*b*

Fig. 4. The Seabee wing float (*a*) is fully monocoque structure fabricated of two pressings automatically riveted along the juncture of outwardly turned flanges. (*b*) Conventional prototype float with the rib members requiring hand riveting through access holes.

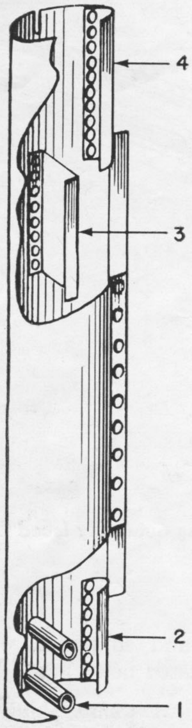


Fig. 5. Wing-float strut assembly: (1) spacer tube for the attachment of bolts at the float; (2) contour plate for the float socket; (3) internal reinforcing channel; (4) contour plate for the wing socket.

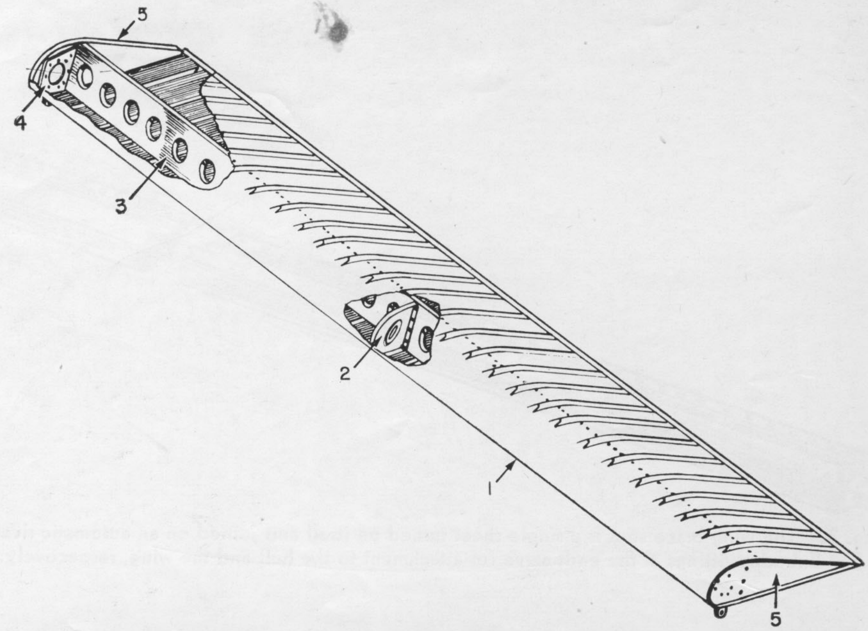


Fig. 6. Structural simplicity is notable in this full-slotted flap: (1) single-piece headed wrap-around skin joined at the T.E.; (2) center nose rib for hinge and horn fitting; (3) spar; (4) ⅛-in. plate stock hinge fitting; (5) end rib.

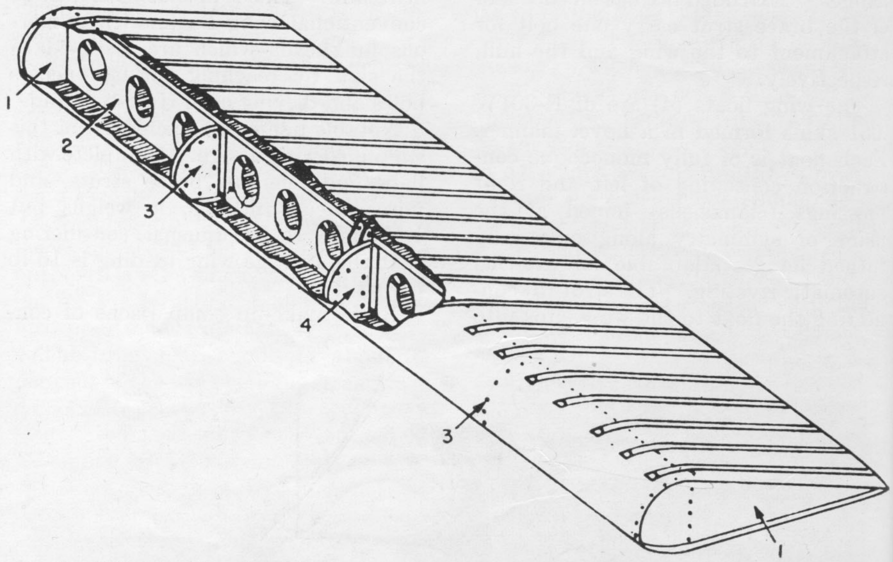


Fig. 7. Like the flap, the full-slotted aileron seen here also has single wrap-around skin. Other details are: (1) end rib; (2) spar; (3) nose rib-carrying hinge; and (4) nose rib-carrying horn. The aileron is identical in cross section to the flap, hence forming tools for latter may be used for the aileron skin, spar, and rib.

tained with the large wing structure justified the application of this theory of simplified and cost-lowering design.

The full-slotted flaps, ailerons, elevators, and rudders, except for size and shape, are fundamentally identical in construction. Each consists of a single beaded skin folded upon itself and joined at the T.E., and each has a single stamped-channel spar member near the leading edge.

The flaps and ailerons have round-nose end ribs, with outwardly turned flanges to afford easy access for automatic riveting. The elevator has only one rib—at the inboard end—bolted to operating torque tube extending between left and right units. No outboard end rib is used because the tip is formed from the skin as a continuation of the T.E. The latter is cut out for a flat stock trim tab at the inboard end, the tab being attached by a piano hinge.

The upper and lower tips on the rudder are fabricated similar to the elevator tip, obviating the need for end ribs.

On the flap (6) there are three ⅛-in. flat-stock hinge fittings. Two are mounted on the end ribs, and the third fitting, which includes an operating horn, is mounted on a center nose rib.

There are two ⅛-in. flat-stock hinge fittings and a separate horn on the aileron (7) which are attached to the intermediate nose ribs.

The spar on the rudder and elevator supports T-shaped extruded hinge fittings.

Since the cross section of the aileron is identical to that of the flap, it is possible to use the flap-forming tools to fabricate the aileron skin, spar, and ribs.

Flap, aileron, elevator, and horizontal stabilizer units are interchangeable with respective opposite-hand installations. Approximate dimensions are: flap, 9½ ft long by 16 in. by 4 in. deep at spar; aileron, 7 ft by 16 in. by 4 in. at spar; elevator (tapered in planform), 6 ft long by 20 in. at maximum chord, tapering to 10 in. at the tip, by 3 in. at average depth at the spar; and rudder (doubled tapered in planform) 8½ ft long by 18 in. at the maximum chord by 4 in. average thickness at the spar.

Hawker Tempest V

The Hawker Tempest V is a low-wing cantilever monoplane. The wings are elliptical in planform and have a laminar-flow high-speed section with maximum thickness at the 37.5 per cent chord. There is no dihedral from the inner portions of the wings, but there is a pronounced dihedral outboard of the landing gear pivots. Ailerons are of the Frise type with split flaps between the ailerons and the fuselage.

Both spars have T-section booms built up of L-section extrusions riveted to heavy-gauge sheet web. Root fittings are shown at (1). The joint in the front spar where the center section and outer panels are connected is shown at (2).

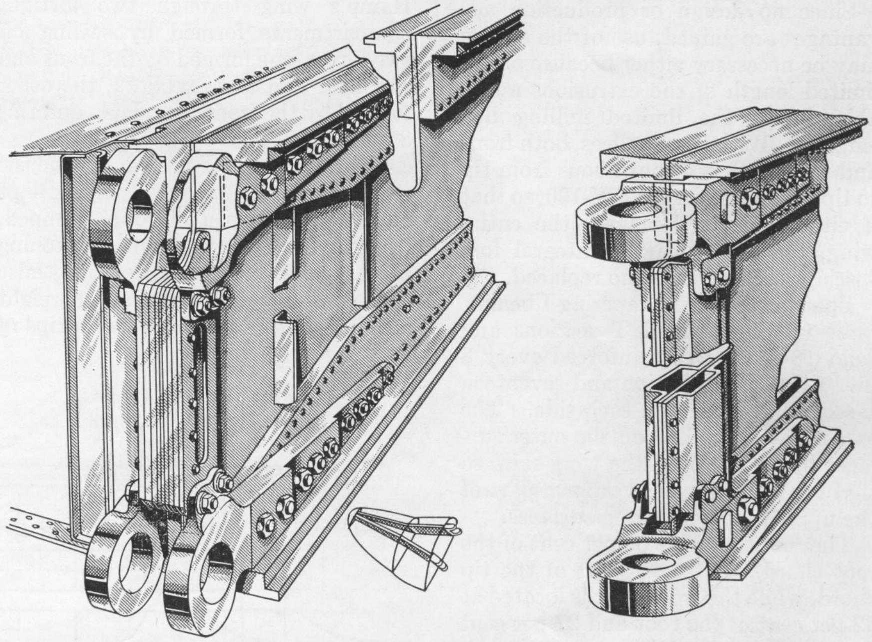


Fig. 1. Cutaway views of the root fittings of a Hawker Tempest V front spar (left) and rear spar (right), with inset sketch showing relative positions in the wing. Both spars have T-section booms built up of L-section extrusions riveted to heavy-gauge sheet web.

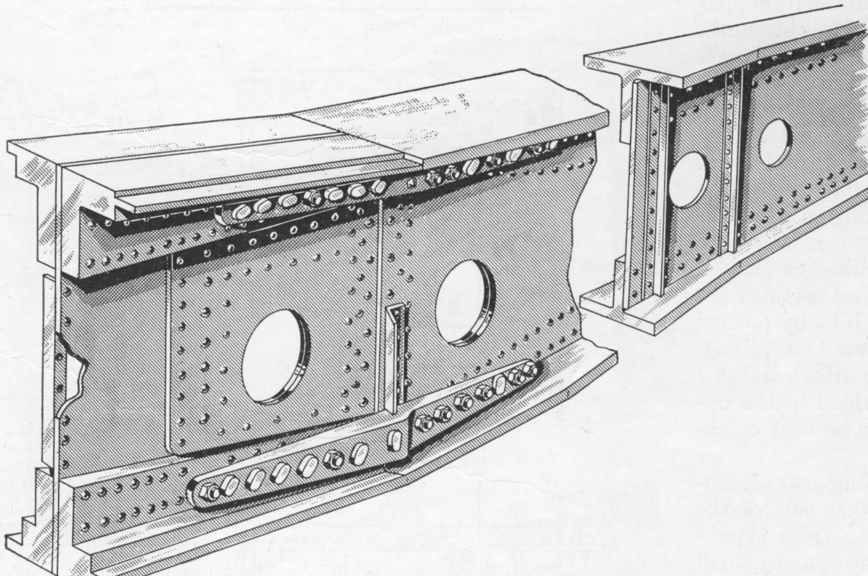


Fig. 2. Front spar of Tempest V where the center section and the outer panel are joined. The center section has no dihedral; the outer panel, which is outboard of landing gear, has 5½ deg. Note that the outer panel booms are normal extruded T sections, as compared with the built-up T sections of the center section.

Zeke 32 (Hamp)

The full cantilever wing of the Mitsubishi Zeke (Hamp) presents several unorthodox features, outstanding of which is the splice on each side between ribs 10 and 11 (1). There are 24 ribs from the fuselage side to the tip.

Since no design or production advantages are gained, use of the splices may be necessary either because of the limited length of the extrusions available, or to the limited milling bed lengths. With these splices, both front and rear spars are continuous from tip to tip, like those on the FW-190, so that if either side is damaged, the entire wing, together with the integral fore fuselage section, must be replaced.

Spars are constant tapering I beams, built up of extruded T sections and solid 16-gauge web reinforced every 8 in. by seven hat-section and seventeen L-section stiffeners on each side. The extrusions are milled on the outer surfaces to the depth of the wing skin, so that the spars themselves form part of the upper and lower wing surfaces.

The rear spar is at 65 per cent of the root chord and 64 per cent of the tip chord, while the front spar is located at 32 per cent of the root and 27 per cent of the tip chord. Distance of the spar centers on the center line of the fuselage is 2 ft 10¼ in.; at the tips it is 1 ft 5¾ in.

Neither upper nor lower surfaces between spars and ahead of the front spar appear to enter beam bending strength, since all hat-section spanwise stiffeners spaced 6½ in. apart in these locations are intercostals, tying only to ribs through flat skin reinforcements.

Open truss-type ribs, spaced 8 in. apart, are used in the landing edge except ribs 4 to 7 for landing gear attachment, and 7 and 8, between which are located the 20-mm Oerliken cannon.

Upper and lower chord sections are J section joined at the L.E. by formed plates. Webs are ⅝-in. OD tubing, flattened at the ends to attach to the J sections. Holes are drilled in the upper ends of the tubes to prevent cracking by flattening.

Nose ribs at the landing gear attachment point and on either side of the cannon are built-up box-truss type—very complex units made of many small parts.

'Tween-spar open-truss type ribs are also spaced every 8 in. Every third rib is a compression member with formed C-section webs using double-flanged gussets at all joints. The remaining ribs, although of similar truss type, are much lighter and are without gussets. Many of the C sections in these ribs have clips at the mid-column point to tie the outstanding legs together and prevent collapse (2).

Additional flotation gear is built into Hamp's wing through two airtight compartments formed by sealing off two boxes, one formed by the front and rear spar and ribs 8 and 22, the other formed by the front spar, L.E., and ribs 8 and 23.

Trailing-edge ribs extending from the rear spar to a false spar supporting flaps and ailerons are conventional stamped, flanged aluminum alloy with lightening holes. Stiffening the Z-section false spar without greatly increasing weight is achieved by screwing small strips of three-plywood both to the inside face and along the flange of the lower edge.

Wing surfaces, like those on the fuselage, are very smooth. Skin panels ahead of the front spar appear unnecessarily small, but those between spars are of normal size. The L.E. skin is .028; top surface between spars out to the cannon between ribs 7 and 8 is .035; from there to the tip, .027; lower surface between the spars is .024; and aft of the rear spar is .022. On the wing, too, very small flush rivets are used, most of them being $\frac{1}{16}$ in.; some are as small as $\frac{1}{32}$ in.

The only anti-icing equipment provided is a slinger ring on the propeller, there being no deicer boots on the wings, and a jacket within the oil radiator to heat the carburetor air.

Made of light alloy pressed in halves

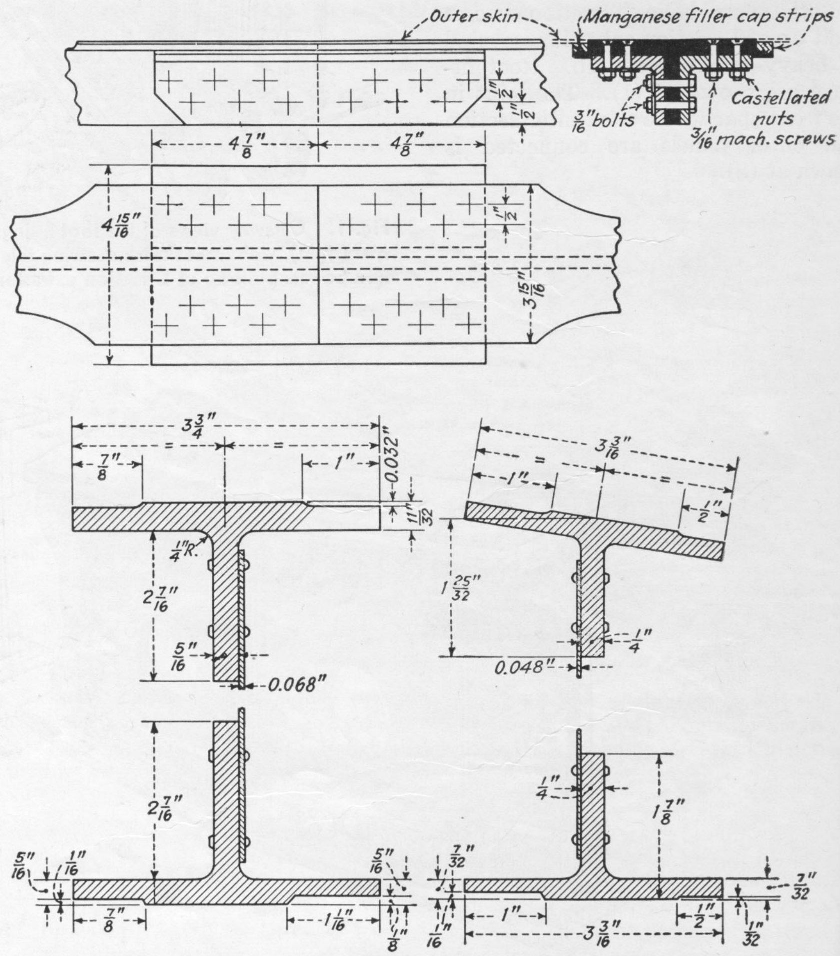


Fig. 1. Plan view and cross section of spar splices, between ribs 10 and 11 on each side, and cross sections with dimensions of the front and rear spars. Flanges of both the top and the bottom extrusions are milled out to depth of flush-riveted skin so that the spars themselves form part of both the upper and the lower wing surfaces.

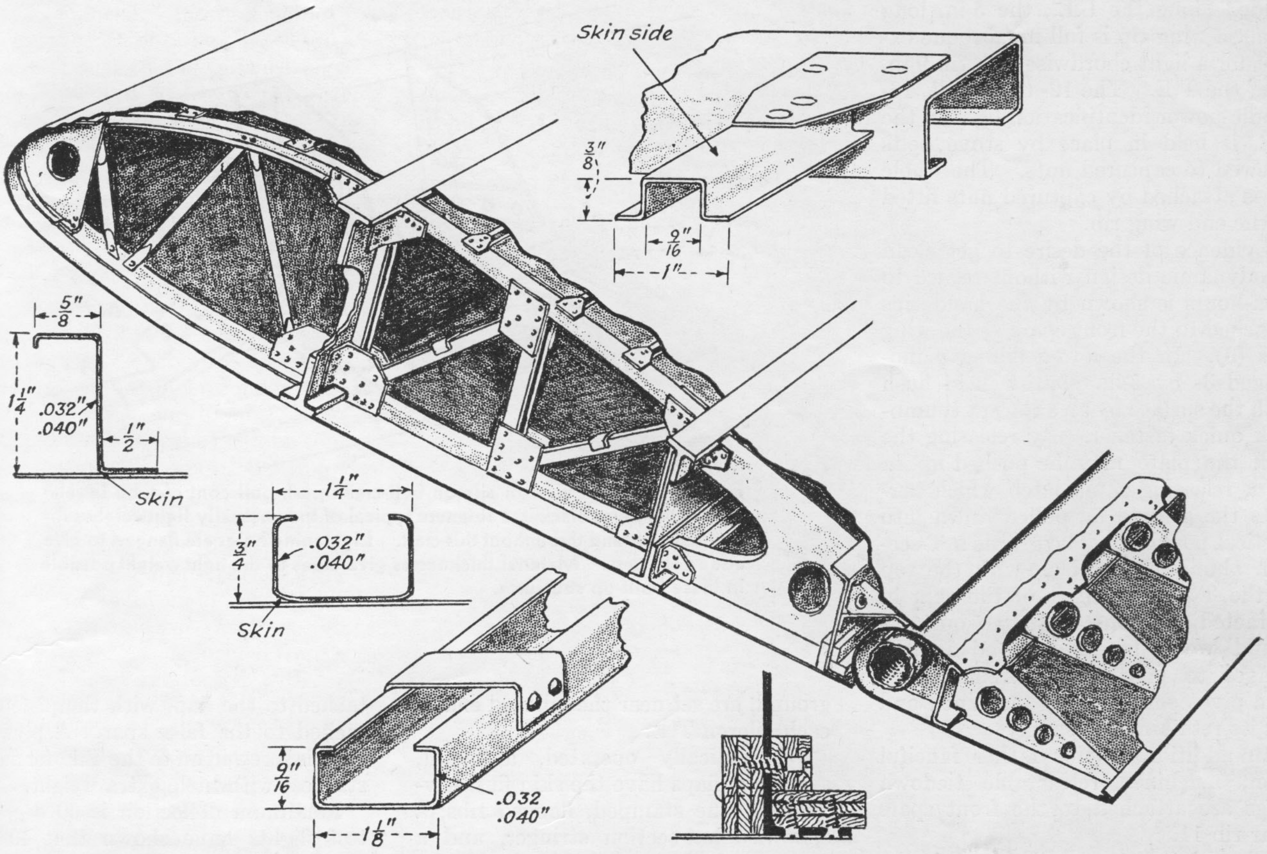


Fig. 2. Cross-sectional view of the wing and aileron, with detail sketches showing dimensions of the various elements and illustrating the use of plywood as a stiffener at the bottom of the false spar to which the aileron is attached, and showing how C sections of inter-spar truss members are reinforced with small riveted clips.

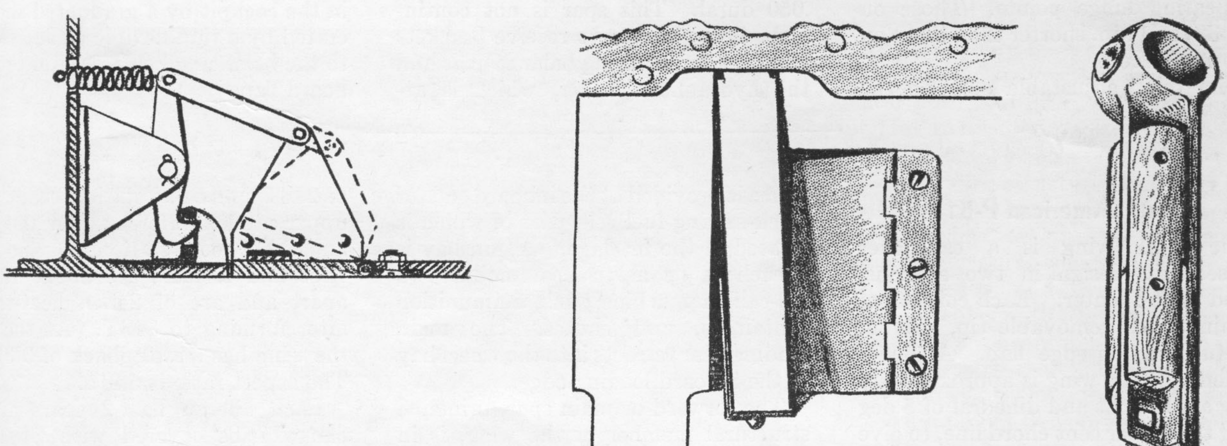


Fig. 3. Flush-retracting handhold attached to the front spar at wing tip. The view from below (center) shows a thumb latch which unlocks the plate (shown attached by a piano hinge) which, when pushed upward, releases the latch and allows the handle to be pulled down into a vertical position. The cross-section sketch (left) shows the operation of the plate and latch; that at the right shows the construction of the grip itself.

welded along the L.E., the 5-in. long squared wing tip is full monocoque except for a light chordwise web rib 9 in. from the T.E. The 12- to 16-volt, 16-candle-power identification light in the L.E. is held in place by stove bolts screwed to captured nuts. The whole tip is attached by captured nuts fitted to the end wing rib.

Evidence of the desire to get clean aerodynamic design without regard to man-hours is shown by the handgrips attached to the front spars at the wing tips (3). In the lower skin a piano-hinged 3- by 5-in. plate is held flush with the surface by an adjacent thumb-lock quick fastener. By releasing the lock the plate may be pushed up, in turn, releasing a pin latch which permits the grip to be pulled down into vertical position. The grip is a T-section aluminum casting—with the top of the T forming part of the skin in retracted position—with two quarter-round wood blocks screwed in the flanges to give a semicircular grip. The pivot end is nicely machined and fits its retaining pin snugly.

In addition to this rather fanciful item, machined retractable tiedown rings are attached to the front spars near rib 11.

The slotted-type ailerons of the Hamp are of conventional design and construction, having a channel-section spar, 15 light stamped ribs and metal-sheathed nose section, all fabric covered and attached at three self-aligning ball-bearing hinge points. Those on Zeke 32 are 11 in. shorter than those on the original Zero.

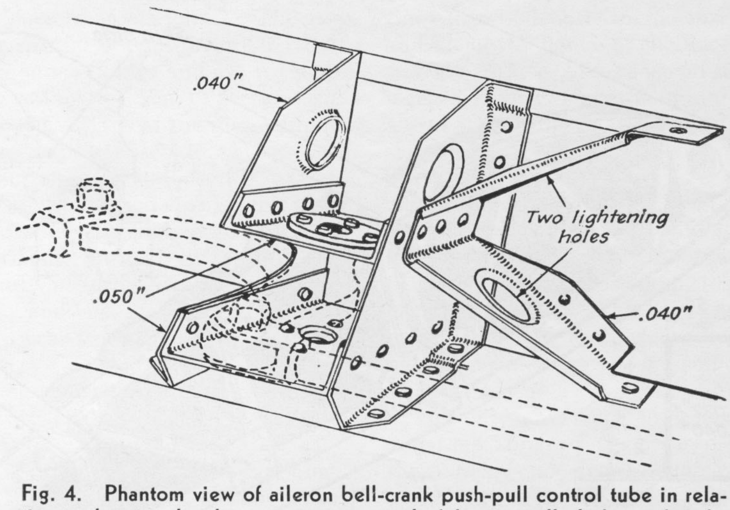


Fig. 4. Phantom view of aileron bell-crank push-pull control tube in relation to the pivot bracket, a structure typical of the unusually lightweight subassemblies found throughout this craft. Lightening holes are flanged to give added stiffness. Material thicknesses give clues to the light weight possible in these built-up structures.

Trim tabs, adjustable only on the ground, are set near the inboard end of each aileron T.E.

Hydraulically operated, all-metal, split-type flaps have the skin flush-riveted to nine stamped, flanged ribs, a spanwise hat-section stringer, and a single spar which is combined with the L.E. by a heavy skin to form a torsion box. Flaps are attached to the false spar by piano hinges. The ribs are .020 gauge; skin is .062 on the bottom of the torsion box, .017 aft; and spar is .050 dural. This spar is not continuous, being broken to receive brackets holding the operating balance gear and the hydraulic cylinder, which is attached to the flap, with the piston attached to the false spar. A plywood strip is screwed on to the T.E. for added stiffness with little extra weight.

Maximum deflection is 60 deg, but test flights have shown that 40 deg gives the best glide angle. To ensure balanced action, two ¼-in. cables are attached to high-tension leads installed aft of the false spar and connected through bell cranks and push-pull rods (4). Operation of the flaps is indicated in the cockpit by a graduated slide operated by a thin flexible cable attached to the balancing bell crank on the starboard flap.

North American P-51

The P-51 wing is a cantilever stressed-skin design in two sections, bolted at the center. Each consists of a main panel, removable tip, aileron, and full trailing-edge flap. Angle of incidence of the wing is approximately 1 deg at the root and dihedral of 5 deg along the 25 per cent chord line, to give stability.

The 25 per cent chord line is perpendicular to the longitudinal axis of the fighter plane. Wing area, including ailerons, is 233.19 sq ft, with span of 36 ft 5⁄16 in., and a taper ratio of .499.

The main wing panel consists of a main spar, pressed ribs, and extruded stringers covered with alloy sheet. Space is provided at the inboard end for a self-sealing fuel cell, part of which is located in the fuselage. A gun bay is in each wing panel to accommodate two .50-caliber machine guns, ammunition containers, and chutes. The main landing gear retracts into the wheel bay in the inboard leading edge.

The forward or main spar, principal structural member of the wing, is in two sections of 24ST sheet spliced together. The inboard spar section is fabricated of 0.129 in. thick 24ST, with angle flanges along both the upper and lower edges for spar caps. A 24ST bar, 0.25 in. thick, is riveted to the inner side of the upper cap between stations 0 and 85.5.

The rear spar is formed of two sheets of 24ST spliced at station 128.6. The upper cap is reinforced by a .091 24SO angle between stations 0 and 92.5. Ribs and formers are about 12.5 in. apart and are of 24SO, heat-treated after forming to 24ST. At the L.E., the wing has a sweepback of 3°35′32″. The aspect ratio is 5.815.

Each aileron has 2 spars and 12 flanged ribs covered with 24ST (1). The forward spar is U-shaped 24ST alclad, and the ribs are 24SO heat-treated to 24ST. The T.E. is 24ST sheet reinforced with aluminum supports and plastic ribs. Three aileron hinge brackets bolted to the forward spar provide bearing attachment points.

The ailerons are dynamically and

statically balanced. Internal aerodynamic balance is obtained by a diaphragm attached to the forward edge of the aileron and sealed to the rear spar by a fabric strip.

Trim tabs of phenol fiber are mounted in each aileron by three hinge bearings. A metal horn tab provides attachment for the actuating rod. The left tab, adjustable in flight, is operated by a knob on the control pedestal. Angular travel, 10 deg up and 10 down, is limited by stops on the cables.

The ailerons are conventionally controlled by the stick, and to meet variations in specifications, they can be connected for angular travel of 10, 12, or 15 deg.

The structure of the 24ST alclad-covered wing flaps is 2 alclad spars, 13 nose ribs of 24SO heat-treated after forming to 24ST, 15 main ribs, and a series of rolled-section stringers, all 24ST. The flap T.E. is formed from a single 24ST sheet reinforced with 27 tapered hat-section supports. Flaps are hinged on three sealed ball bearings and are hydraulically controlled by a lever on the control pedestal. The position of the lever selects and holds any corresponding position of the flaps.

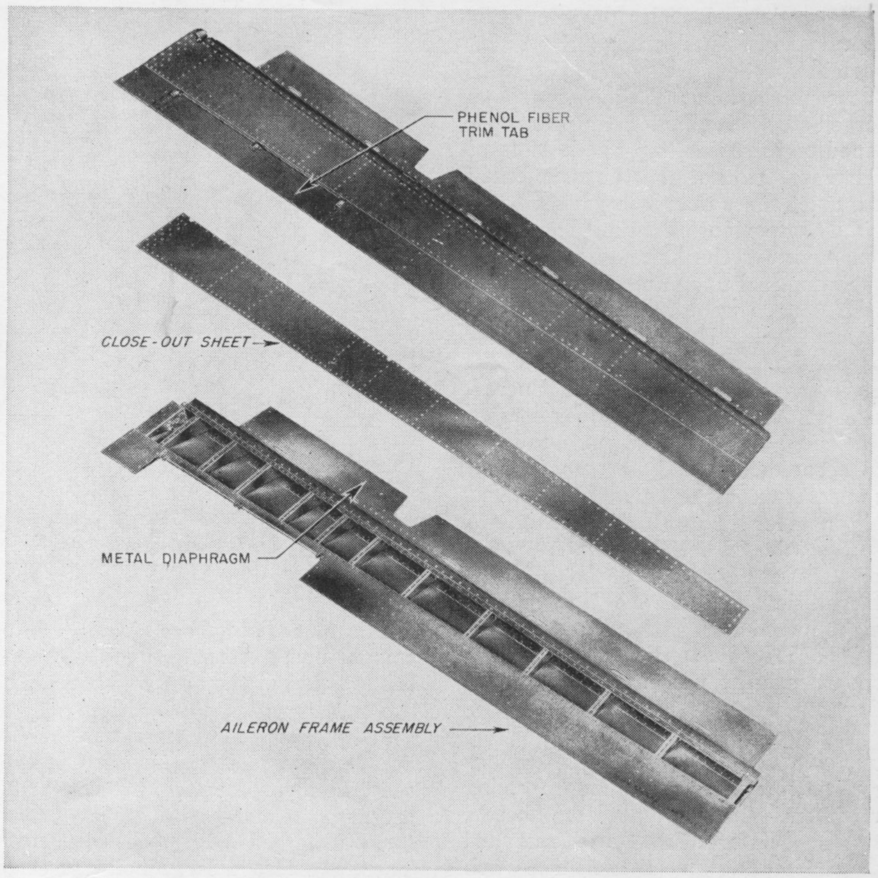


Fig. 1. The ailerons are built of 24ST with plastic tab. A metal diaphragm retains aerodynamic smoothness at the joint with the wing.

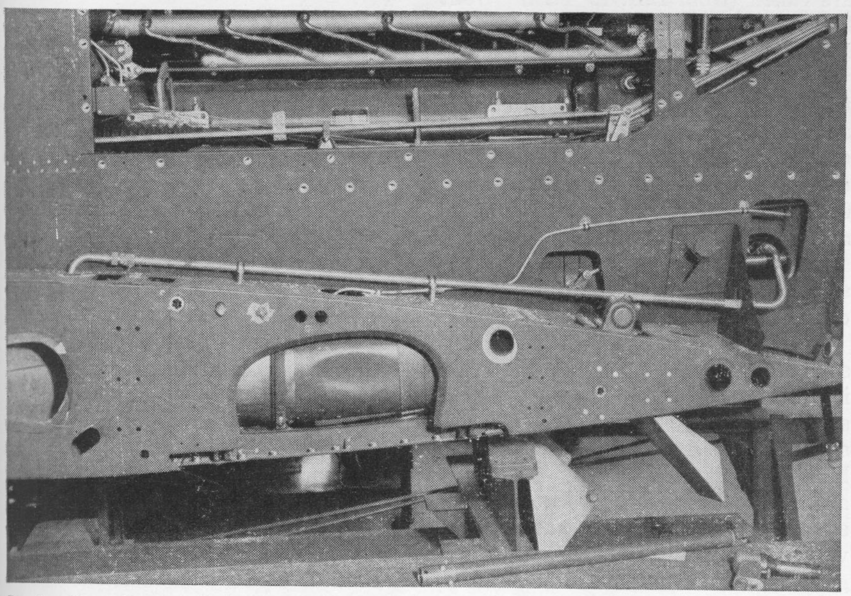


Fig. 1. The relation of the wing center section to the fuselage assembly is shown here. Note the oil radiator installed in the wing section.

Bell P-39 Airacobra

The Airacobra's wing center section is in two parts, forward and trailing edges, both of which are designed as integral parts of the forward fuselage and wing outer panels.

The forward structure is built in six main parts: a forward and a rear beam corresponding exactly to the main beams in the outer wing panels, two inner bulkheads, and two outer bulkheads for splicing to the outer panels.

The forward beam consists of top and bottom capstrips of milled extruded-aluminum shapes, tied by heavily reinforced aluminum webs in four principal panels. The two inside panels are solid single-layer pieces. The outside web panels are made up of three layers of heavy-gauge aluminum, the center layer acting as a reinforcing member. The outside layers have formed 90-deg flanges at the edge. These web layers have a dual function and must be rigidly constructed. Large oval-shaped holes are cut through their centers to

accommodate oil-cooler ducts extending from the wing leading edge to oil coolers installed in the aft portion of the center section. In addition, four forged-steel wing-bolt fittings are fastened on each side, top and bottom of these web panels. In the main, they are much more than web panels, being vitally important structural members.

Except for the aluminum capstrips superimposed upon and riveted to the steel flanged web, the rear beam is all formed steel. The web is in two layers or sections riveted back to back. Strength considerations made it necessary to use steel for this member because four large holes are cut in the web to accommodate air ducts for the oil coolers (two outside circular holes), and air ducts for the Prestone radiator (two square inboard holes), which also is located in the aft portion of the wing center section. As in the front beam, eight forged-steel fittings for the wing bolts are riveted to the steel web, lying snugly against the capstrip and side flanges.

The two internal bulkheads consist of reinforced-aluminum web sections riveted to extruded-aluminum forming members. The outboard bulkheads, too, are reinforced webs with extruded angle forming members. The web sections are heavily reinforced where the wing bolts run through from the outer panel beams to fittings in the center section beams.

Top and bottom skin sections are formed-aluminum sheet, reinforced with angle stringers and heavy plate where holes are cut for wing-bolt access doors.

The T.E. of the wing center section consists of a single beam which acts as a carry-through member for the auxiliary beam of the outer wing panels. This beam is built up of formed sheet. Its sections are tied across by a heavy T-section extrusion further reinforced by extruded angle sections. Each side is cut through to accommodate air ducts to the Prestone radiator, which is mounted just aft of these beams and extends up through the longitudinal beams of the forward fuselage.

Extending forward from the beam are parallel extruded channel sections to which outboard splicing bulkheads are riveted and upon which the partial skin covering is placed and riveted. Forged fittings are riveted to the auxiliary beam for additional wing splice bolts, and the bulkhead is strongly reinforced at these points.

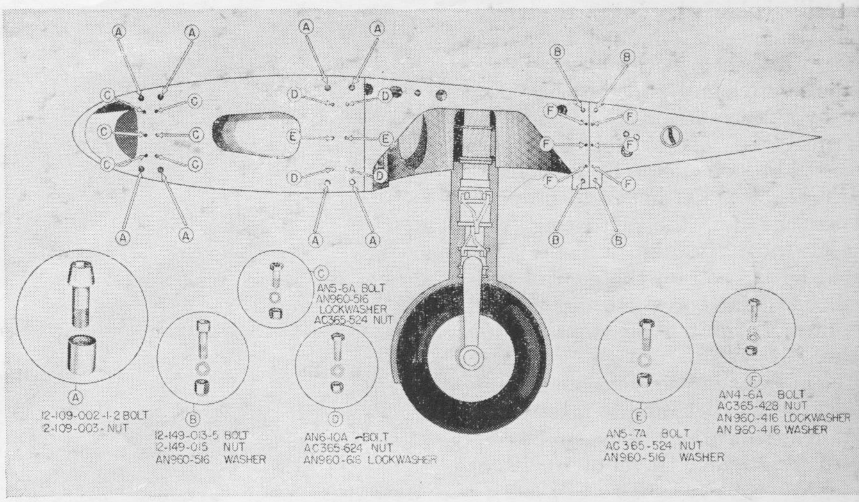


Fig. 2. Details of the wing splice bulkhead showing wing bolts and their location.

The oil radiators are strapped into compartments formed by the bulkheads ahead of the auxiliary beam (1).

The outer wing panels are joined to the center wing section on each side at approximately 22 in. outboard of the center line of symmetry. Thirty bolts are used to make each splice (2), 12 are cold-forged with recessed heads. There are also 4 large bolts at each front and rear beam connection, and 4 smaller ones at the auxiliary beam. In addition, 6 regular hex-head bolts are used at each of the three beam splices.

The three outer wing panel spars (3) are called (from L.E. to T.E.) "front beam," "rear beam," and "auxiliary beam."

Front and rear beams consist of flanged capstrips of extruded-aluminum shapes milled to distinctive and exacting dimensions with the flange thickness tapering from a maximum of 0.865 in. at the inboard end to 0.154 in. at the outer tip. Solid heavy-gauge aluminum sheet webs with occasional stringers complete the beam construction.

Formed aluminum capstrips with a solid aluminum web make up the auxiliary beam. The top capstrip is in dual sections running from the inboard splice bulkhead to just beyond th fifth bulkhead. In the T.E. assembly, an intercostal beam is installed for strength and also forms a compartment with the auxiliary beam for the flap-actuating push-pull rod assembly. Running between the first and third T.E. bulkheads are short beams to support the wing catwalk. The T.E. strip is a drawn aluminum piece which clamps round the skin and is held together by rivets.

There are 13 principal wing panel bulkheads of pressed and beaded aluminum, ranging in gauge from .072 for the inboard splice bulkhead to .064 for the wing-tip splice bulkhead.

Bulkheads are numbered in stations from 1 to 10 in the Bell production setup. Counting inboard, the first seven bulkheads are whole-numbered stations; the eighth is station 7.5, and each represents a half station from there to the thirteenth bulkhead at station 10 (4).

Self-sealing fuel cells are accommodated by compartments formed by bulkhead station 2 to station 7.5 between the front and rear beams. A longitudinal bulkhead between stations 4 and 5, about one-third of the distance forward from the rear to the front beam, forms a compartment for the main landing gear retracting spindle assembly. Twin .30-caliber machine guns are installed between stations 7.5 and 8, with a false-rib bulkhead between them.

An intercostal beam of formed, blanked, and beaded aluminum sheet webbing between drawn aluminum capstrips runs between stations 8 and 10, about midway between the front and rear beams, forming a compartment with the front beam to accommodate wing ammunition boxes.

Landing gear wells between stations 1 and 2 are shaped of formed and drawn aluminum capstrips with formed aluminum sheet webbing. Two angle

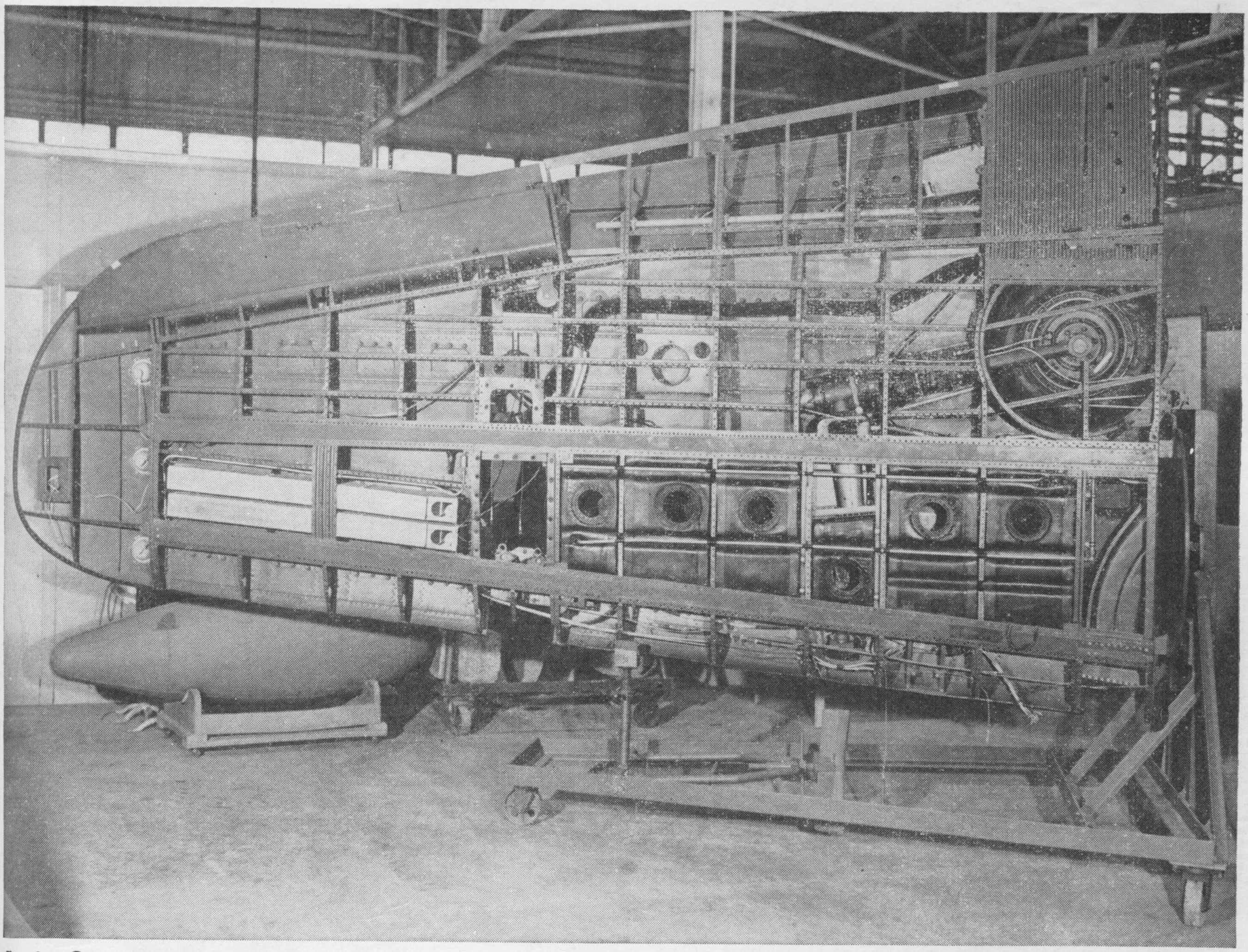


Fig. 3. Outer wing panel with the top skin off to show self-sealing fuel tanks, wing-gun ammunition boxes, retracted main landing wheel, and machine-gun heater tube. Note the push-pull rod for actuating the landing flap.

shaped stringers extend from station 1 bulkhead over the top of the wheel to the outer periphery to reinforce the wing catwalk.

The wing-skin lower surface is formed in three main sections: forward and aft of the rear beam, and the L.E. Each section consists of two panels running inboard to about station 7.5 and from there to station 10.

The two aft panels are .025-gauge formed sheet with numerous reinforced access door cutouts. The inboard panel between the rear and forward beams is .051-gauge formed sheet, largely built up with reinforcing panels. The outboard front panel is .032-gauge sheet with a large access door of the same gauge aluminum for the wing ammunition cases. The L.E. is .032-gauge formed sheet.

From top to lower surface the skin consists of panels similar in gauge and arrangement. The inboard forward panel has a number of reinforced access holes for fuel tanks; the outboard forward panel has a large door for installation or removal of wing guns. Skin stringers are, for the most part, Z-section, rolled, or drawn aluminum. Flush riveting is used throughout.

The wing tip is composed of two bulkheads and three tapering beams. The wing splice bulkhead is built up of rolled capstrip and sheet webbing of .064-gauge aluminum. The internal bulkhead is in three sections, each of formed beaded sheet, with a series of beaded lightening holes. These bulkhead sections are riveted to the beam. The beams are also formed and blanked sections; the T.E. beam is riveted to the rear section internal bulkhead in two sections. Skin stringers are drawn hat sections riveted across the beams The tip edge is a formed aluminum strip enclosing the skin, which is .032 gauge, entirely flush-riveted.

The fabric-covered ailerons are monospar structures of the Frise type with built-up ribs of extruded shapes, in some cases, and formed ribs in others (3). The built-up ribs, tied together with gusset plates, are capstripped with metal channel assemblies used in conjunction with thin metal retainer strips to tie down the fabric skin covering, giving a flush surface. The L.E. ribs are formed and blanked sheet riveted to the .040-gauge alclad beam. The T.E.'s are formed strips enclosing the skin fabric.

Controllable trim tabs of laminated phenolic plastic are located at the T.E. of each inboard aileron (3). These trim tabs also act as a servo control

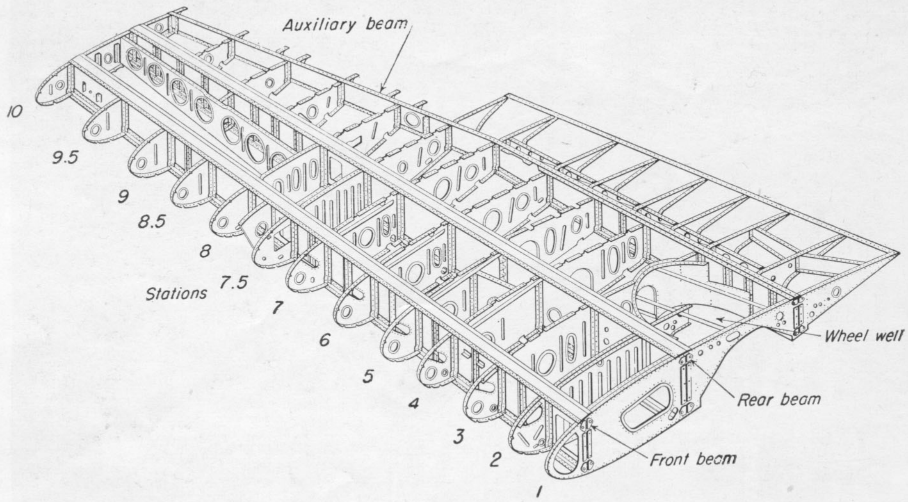


Fig. 4. Outer wing panel skeleton showing stations and details of the beams and bulkheads.

through a mechanical linkage which automatically rotates the tab to an angle opposite to the movement of the aileron and creates a force which reduces the energy required to actuate the aileron. An additional servo tab of laminated plastic, not controllable by the pilot, is located just outboard of the trim tabs. The servo tabs are actuated by a mechanical linkage attached to the aileron hinge bracket maintaining the servo tab at a neutral setting 2 deg above the thrust line of the plane with the ailerons positioned at any angle in flight.

Split T.E. type of wing flaps form the lower rear surface of the outer wing panels. They extend from station 1 to the inboard end of the aileron. Attached to the wing by a piano-type hinge extending the full flap length,

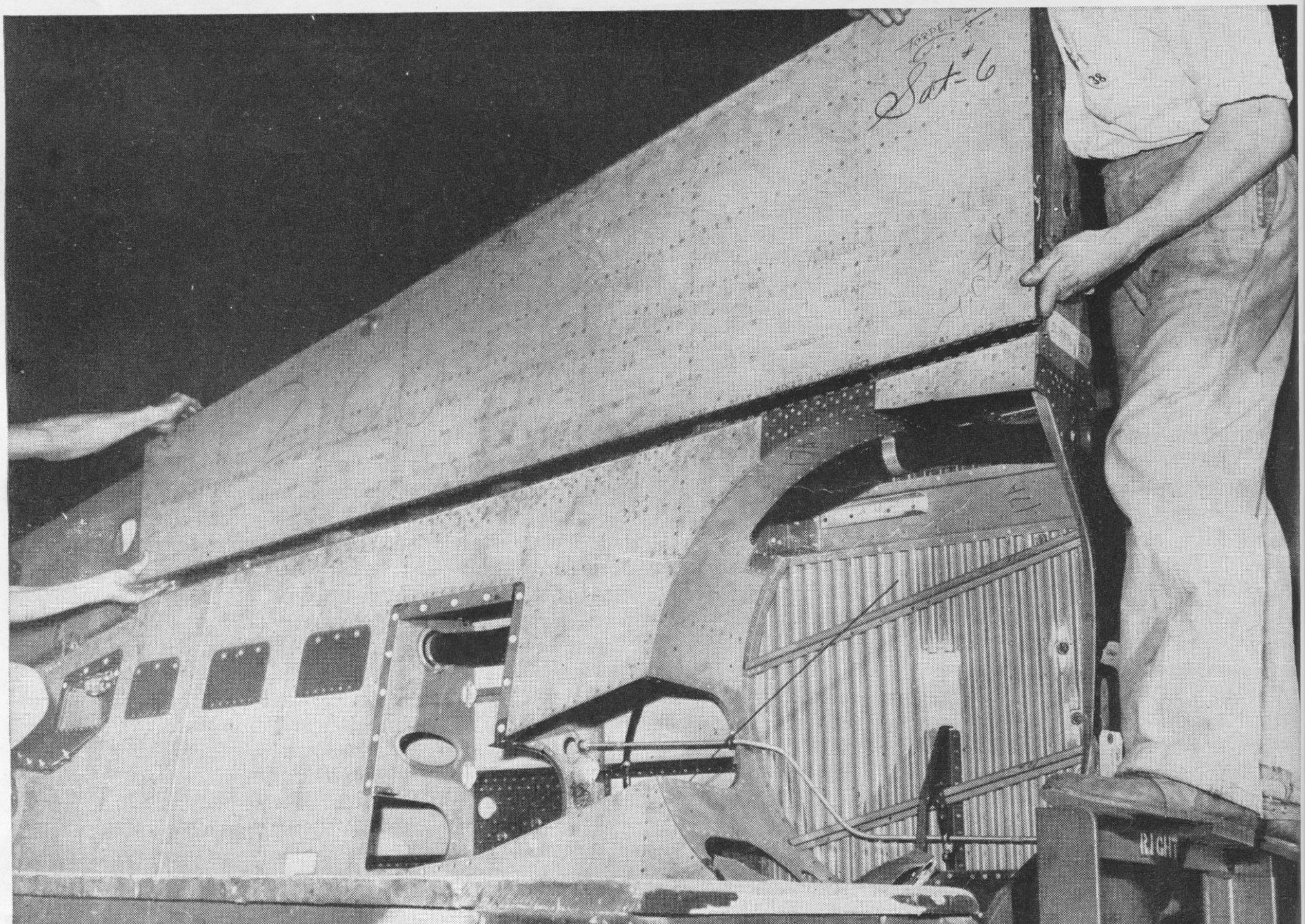


Fig. 5. Attaching the landing flap to the wing auxiliary beam. The underside of the top skin shown through the wheel well is corrugated to provide strength for the catwalk. Note the heater hose for the wing guns.

they are connected to the auxiliary beam lower flange (5). Flaps are operated by a push-pull tube and an electrically driven connecting link mechanism (6). The operating member consists of five turnbuckle connecting links between the flap beam and the push-pull tube.

The single beam is a formed channel section of .040-gauge aluminum. The ribs are formed solid sheet sections in two parts, riveted fore and aft of the beam. The skin stringers are also formed channel flanged sections. The skin is a solid panel of .025-gauge sheet. A doubler sheet with a number of blanked lightening holes is riveted to the ribs forward of the beam. The flaps are stressed so that full extension (43 deg) may be used at 150 mph maximum speed.

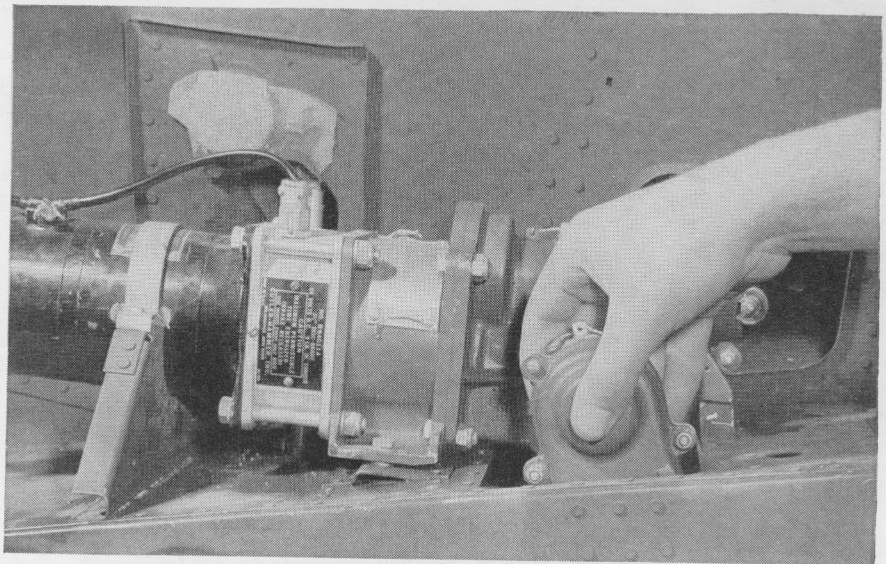


Fig. 6. The landing flap is powered by ½-hp electric motor located on the beam deck of the forward fuselage.

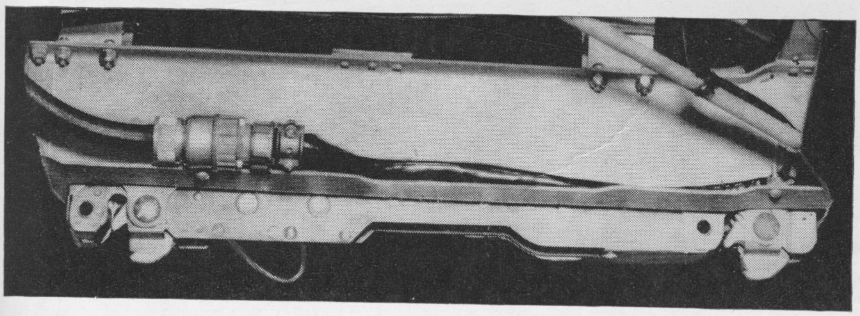


Fig. 1. Exploded view of Republic P-47N Thunderbolt aileron. Part of upper skin is omitted to the show construction of the L.E., spar, and ribs.

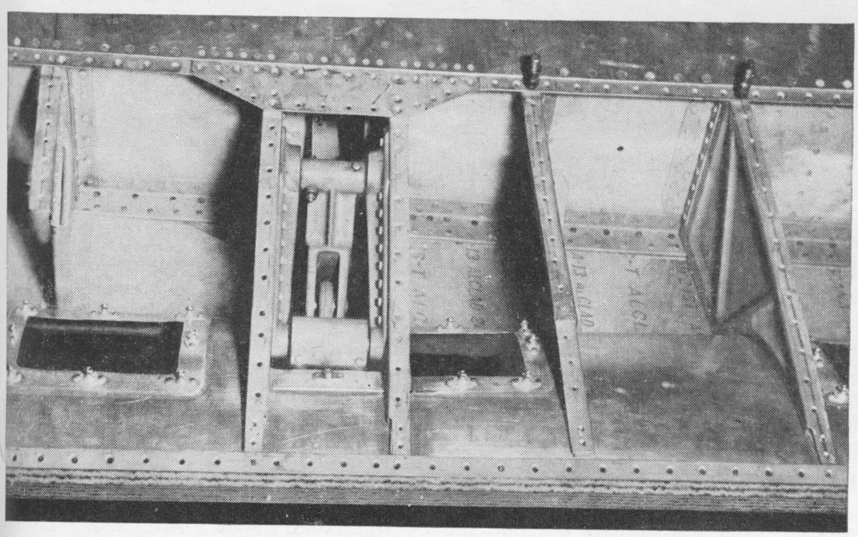


Fig. 2. Close-up of P-47N wing bomb rack and shackle structure which is attached outboard of the landing gear between two main spars.

Republic P-47N

Multicellular construction is used in the P-47 wing which consists of two main spars and three short auxiliary spars constructed of sheet-metal webs with flanges and angle stiffeners. The entire structure is of aluminum-covered aluminum alloy (24ST alclad), aluminum alloy forgings (14ST and 24ST), and chrome nickel–molybdenum steel forgings (X4340).

The angle of incidence and the amount of dihedral are fixed, and there are no provisions for changing them.

Of stressed-skin type, the upper and lower surfaces are reinforced by extruded angle stringers attached under the skin. Transverse rigidity is obtained by ribs between the spars and attached to the spars and to upper and lower skin surfaces. Four interconnected self-sealing fuel cells are incorporated in the root of each wing panel.

The main wing panels are attached to the fuselage by four pairs of pin connections, one pair for each main spar at each side. Attachment is made by tapered bolts which expand split bushings to a tight fit in reamed holes, thus removing the "play" from the connection. Access to the completely enclosed attachment is gained by removing the fillet fairing cover strips. A main panel may be removed from the aileron (1), with flap, tip, and landing gear in place, or these units may be removed separately.

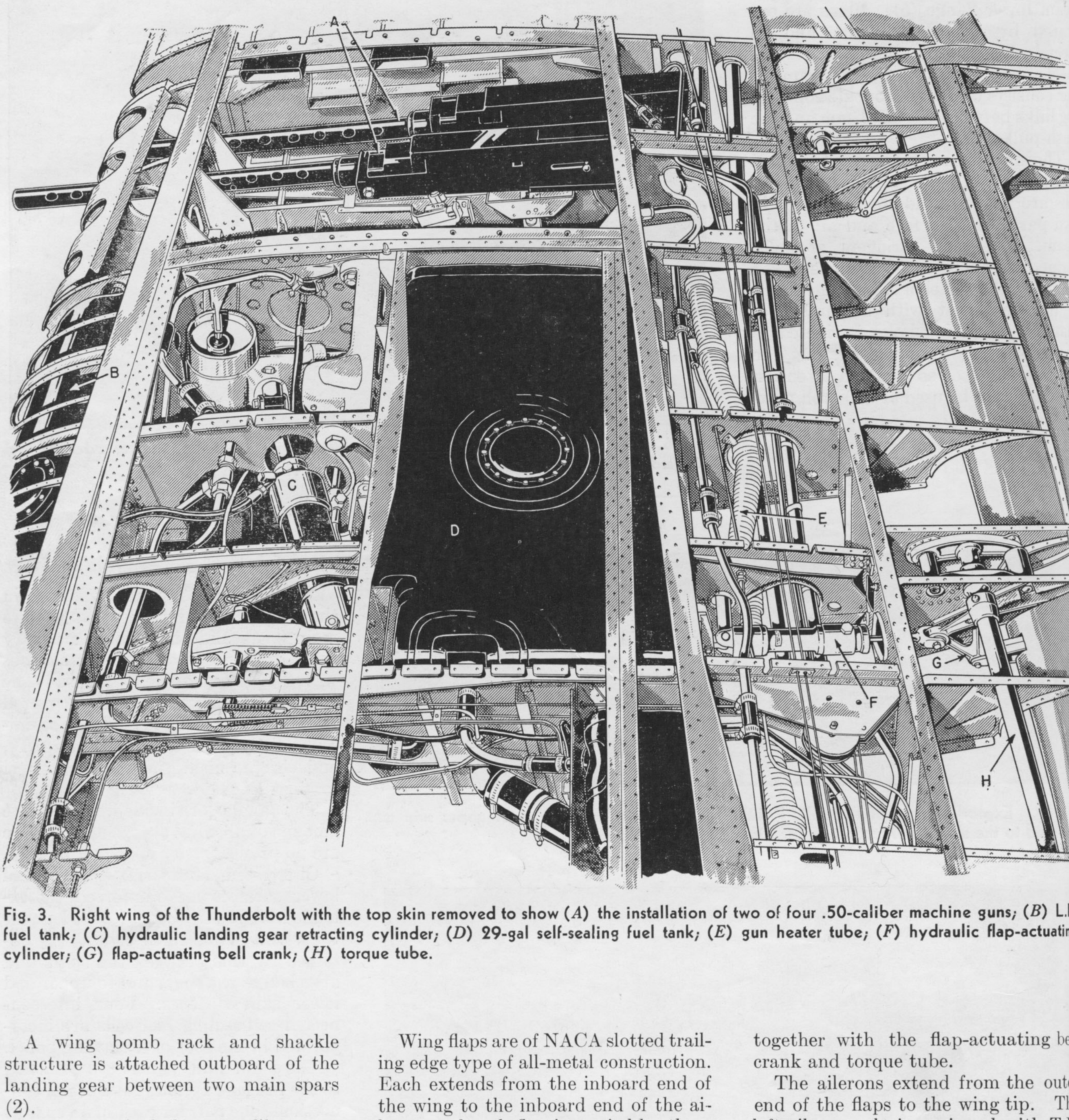


Fig. 3. Right wing of the Thunderbolt with the top skin removed to show (*A*) the installation of two of four .50-caliber machine guns; (*B*) L.E. fuel tank; (*C*) hydraulic landing gear retracting cylinder; (*D*) 29-gal self-sealing fuel tank; (*E*) gun heater tube; (*F*) hydraulic flap-actuating cylinder; (*G*) flap-actuating bell crank; (*H*) torque tube.

A wing bomb rack and shackle structure is attached outboard of the landing gear between two main spars (2).

Armament includes .50-caliber guns installed in the wings. These guns are mounted in pairs in each wing, those in the right panel being shown in (3). Heat is supplied to the machine guns through a flexible metal tube running through the wing structure just ahead of the flaps. In addition to the fuel tanks installed in the leading edge, self-sealing tanks are mounted between the spars.

Wing flaps are of NACA slotted trailing edge type of all-metal construction. Each extends from the inboard end of the wing to the inboard end of the aileron, and each flap is carried by three trapezoidal linkage hinges supported by spar (4). Doors, linked with and operated by the flap-operating mechanism, close the slot between the leading edge of the flap and wing proper when in normal UP position.

Flaps are hydraulically operated, receiving fluid and pressure from the main hydraulic system. The flap-activating cylinder is shown in (4) together with the flap-actuating bell crank and torque tube.

The ailerons extend from the outer end of the flaps to the wing tip. The left aileron only is equipped with T.E. trim tab which is controllable in flight. Ailerons, except fittings, are constructed of aluminum-covered aluminum alloy (24ST alclad). The trim tab is of similar construction. Three forged-aluminum alloy hinges with ball bearings are used to attach each aileron to auxiliary spar 3 outboard. The operating horn is located just outboard of the center hinge.

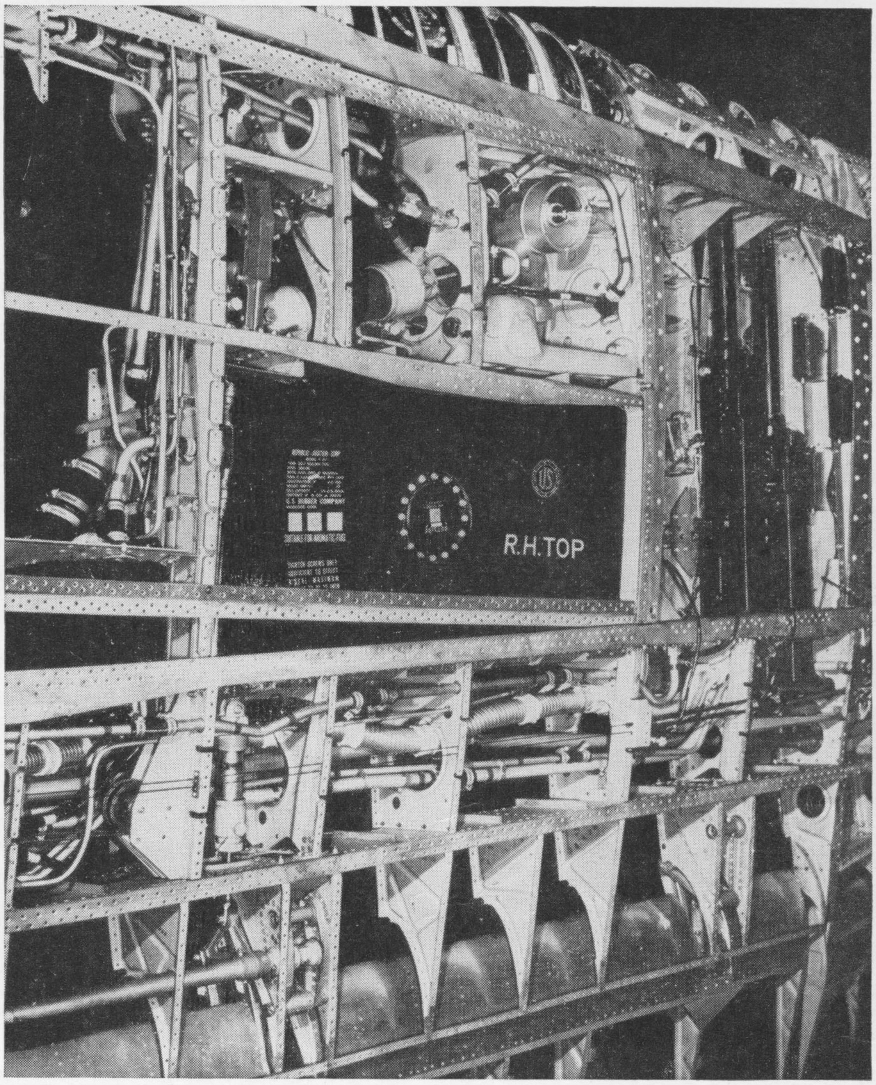


Fig. 4. Detail of P-47N wing seen from aft of the T.E., showing the false spar and rib structure around the flap-actuating bell crank. Quickly removable inspection panels are seen on either side.

Fleetwings BT-12

One of the most striking examples of what has been done with stainless-steel construction is the use of the structural space in the torque box of the center wing section of the BT-12 for an integral fuel tank which has proved one of the most successful of this type.

The first attempts at construction by spot welds and solder were not very successful, but the seam-welding technique, which is actually a series of overlapping spot welds performed by roller electrodes, has effectively solved the problem. Tanks remain leakproof in use under vibration tests; except for some trouble with the aluminum sump attachment which was soon corrected, the tank outlasted the test table.

The skin and corrugation in fueltight bulkhead are seam-welded through flanges of the front and rear spars. The end bulkheads are seam-welded through reinforcing plates to a U-shaped member on its side, which forms the joint between the inner and outer reinforcing plates, bulkhead, and covering on each side of the bulkhead. The sump at the bottom of the tank is an aluminum casting bolted into a formed stainless-steel collar. Two standpipes into the tank provide for the main and reserve fuel supply. The filler neck is accessible through a hinged flap in the leading edge, which is itself removable for inspection of the forward spar and tank.

The center trailing rib section is made to be easily removable or replaced, the ribs being bolted to the rear face of the rear spar. A walkway next to the fuselage is also built into the wing flap at this point. Flush-fitted fabric covering is fastened down into M-section capstrips by an .008-gauge stainless retaining strip over reinforcing tape secured by flathead sheet-metal screws and covered by tape strips.

Built of stainless, D-section mono-

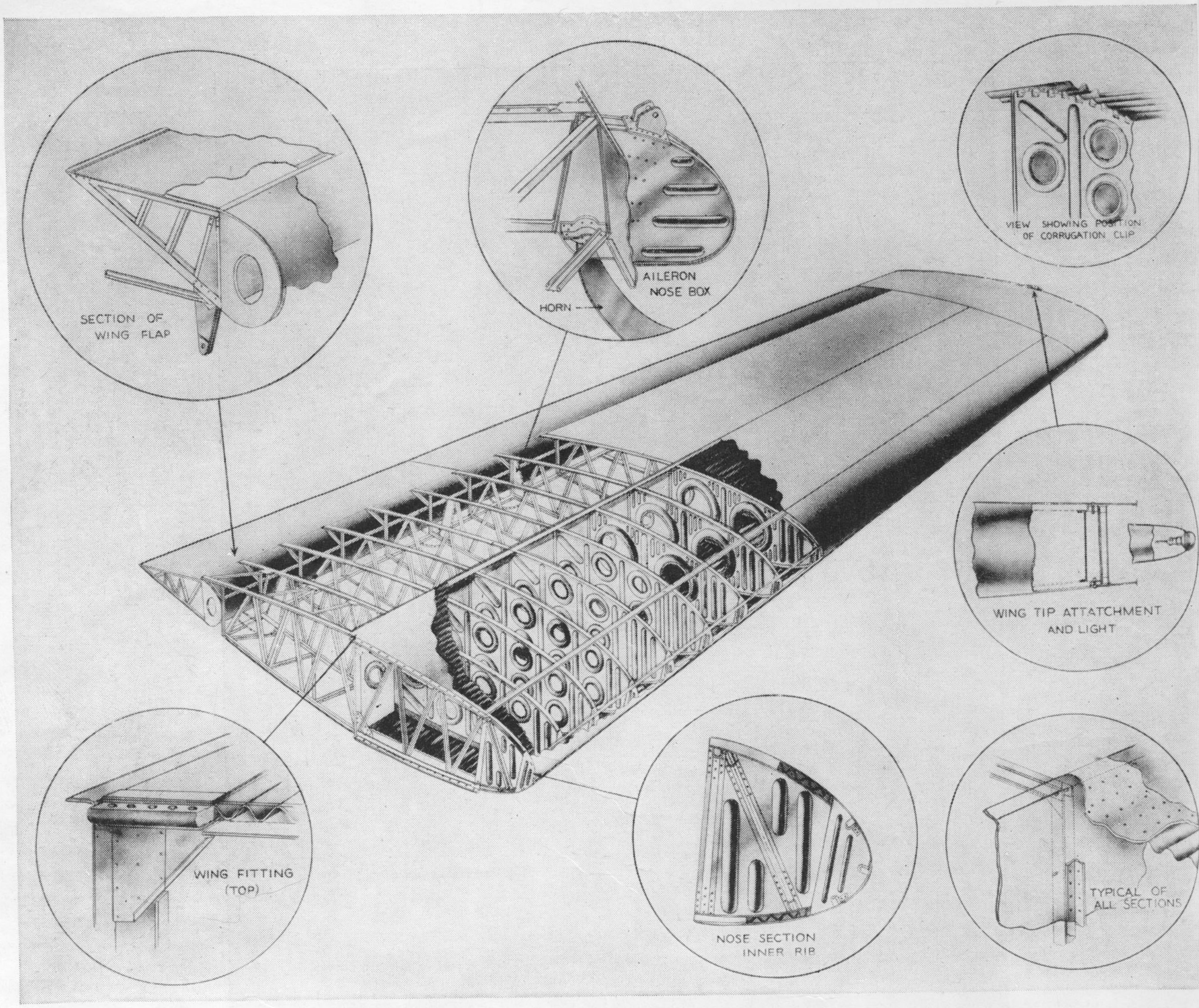


Fig. 1. Wing outer panel, made of stainless steel and built around the main spar, is 0.030 to 0.025 in. thick. The front spar, L.E. formers, and stamped ribs, trailing ribs, and top skin are 0.010 in. thick. The L.E. skin is 0.020 to 0.016 in. thick.

spar, with flush fabric-covered trailing rib section, the outer wing panels (1) are joined to the center section by stainless-steel bars at top and bottom and fastened by $\frac{5}{16}$-in. screws and channel nuts. The web of the outer spar bolts to the rear spar of the center section, and a reinforced vertical-angle piece welded to the outer wing bolts to the web of the front center section spar, thus giving attachment around four sides of the center torque box. The joint is further strengthened by finger plates which underlie the attaching bars at top and bottom, and they are welded back to the corrugation for several inches. The stainless skin butts up flush; while to the rear, gap strips cover the joint.

Spar section ribs are rubber press-formed annealed stainless, reinforced at the flange caps by narrow strips of the same gauge welding inside the upper and lower flanges. The skin and corrugation are welded together before application by a rolling welder which spot-welds the skin to two rows of the corrugation at the same time.

Finished sheets of skin and corrugation are applied as a unit. Ribs are fastened to the corrugation by means of annealed stamped clips, which are welded to the corrugation before application of the skin. Ribs fit into the clips and are welded in place. This method, used throughout the plane, makes a strong homogeneous structure.

Trailing-edge ribs are built-up members. They are connected at the rear by a false spar to distribute concentrated loads from hinge ribs to adjacent ribs, and to provide contour for the fabric covering. Aileron hinge brackets are made up of two stainless plates, one of which is stamped into a hat section over which is welded the other flat plate. The stamped piece is annealed, the flat plate is full hard. Hinge bearings throughout the plane are self-aligning ball bearings. Hinge pins are all standard AN4 clevis bolts.

Detachable plywood wing tips are fastened to the outer panel by Phillips-head screws. The fastening strip of the wing tip fits over a recessed strip on the outer panel, bringing the wing tip flush with the rest of the wing. Construc-

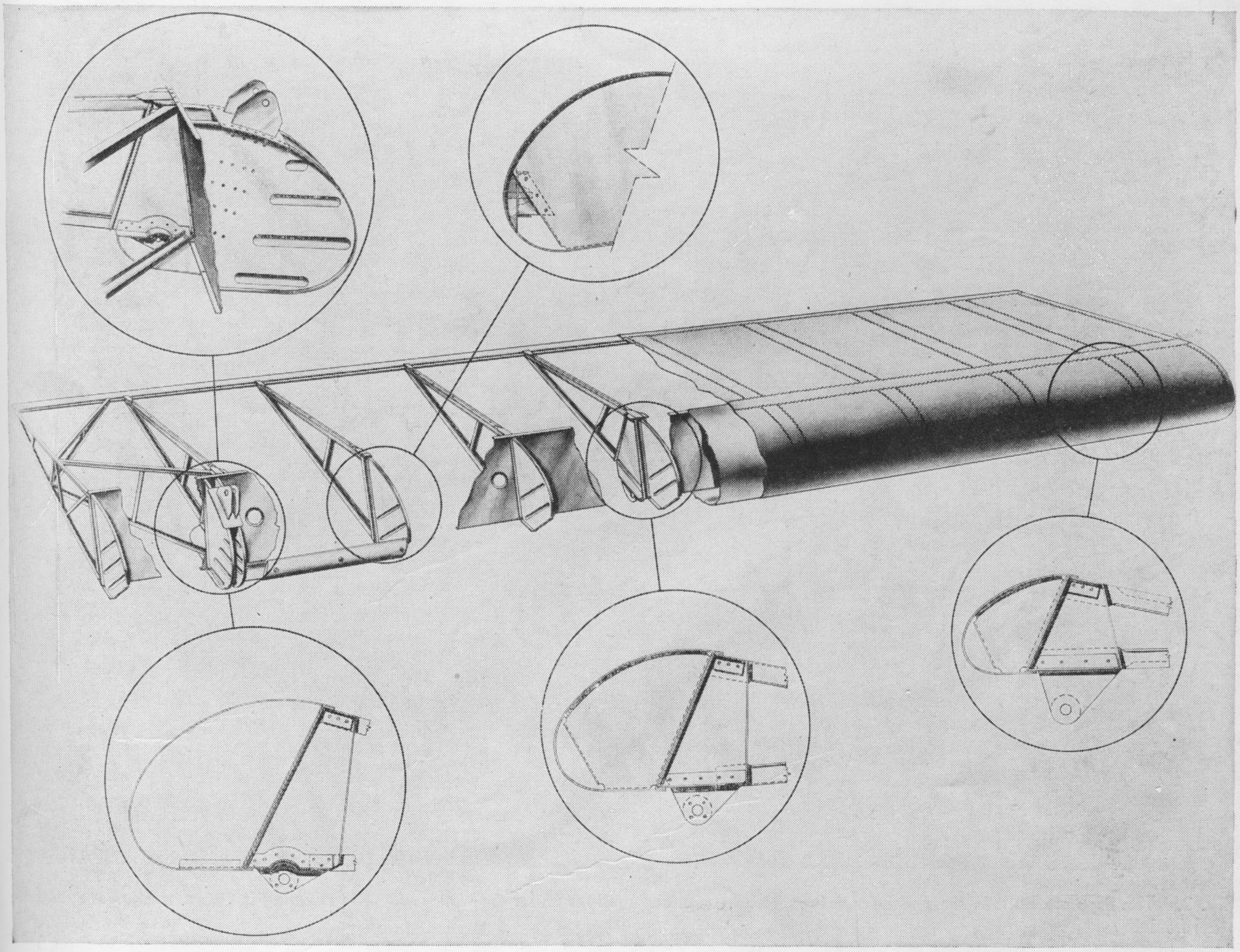


Fig. 2. Fabric-covered ailerons built on a D-section box spar. The ribs are built up from 0.008-in. stainless steel. The hinges are 0.040 in. thick; horn, 0.050 in. The aileron area is 21.4 sq ft.

tion is of poplar core, two-ply mahogany, 1/16 in. thick, with a bow member and four web and cap forming ribs.

The ailerons (2) are Frise type, torque box, flush-fabric covered, with annealed stamped L.E. ribs and built-up trailing ribs. Although the forward box section is stainless covered, the fabric is wrapped over the entire aileron. There is one trim tab on the left aileron. Aileron horns consist of two full-hard stainless plates welded to the nose ribs and protruding through the nose skin.

Of the same construction as the ailerons, flaps (3), however, are divided into center and outer sections, because of the dihedral angle at the joint of the center section and outer panel. A stainless-steel walkway of corrugation with skin covering is built into the inboard end of the center section. The upper surface of this section is flush-fabric covered, while the undersurface is covered with 12-oz canvas duck to withstand the impact of stones or other objects thrown up during landing or take-off. The outer flap sections are flush fabric-covered both top and bottom. The control horns are similar in design and construction to the aileron horns.

Airfoil Data

Root section	NACA 23016
Tip	NACA 4408
Root chord	7 ft 3 in.
Tip chord	3 ft 8.22 in.
Taper ratio	2:1
Angle of incidence, root	1.5 deg
Angle of incidence, tip	−2 deg
Dihedral (measured on top face of front beam)	5 deg
Sweepback, L.E.	7 deg
Max. rib spacing	12 in.
Spar locations:	
Main shear web, root	40% of chord
Tip	30% of chord
Aspect ratio	6.8
M.A.C. length	75 in.
Location:	
Aft of L.E. at root chord	6 in.
Above L.E. at root chord	4.2 in.
Aileron location (distance from plane of symmetry to centroid of aileron area)	14 ft 7 in.

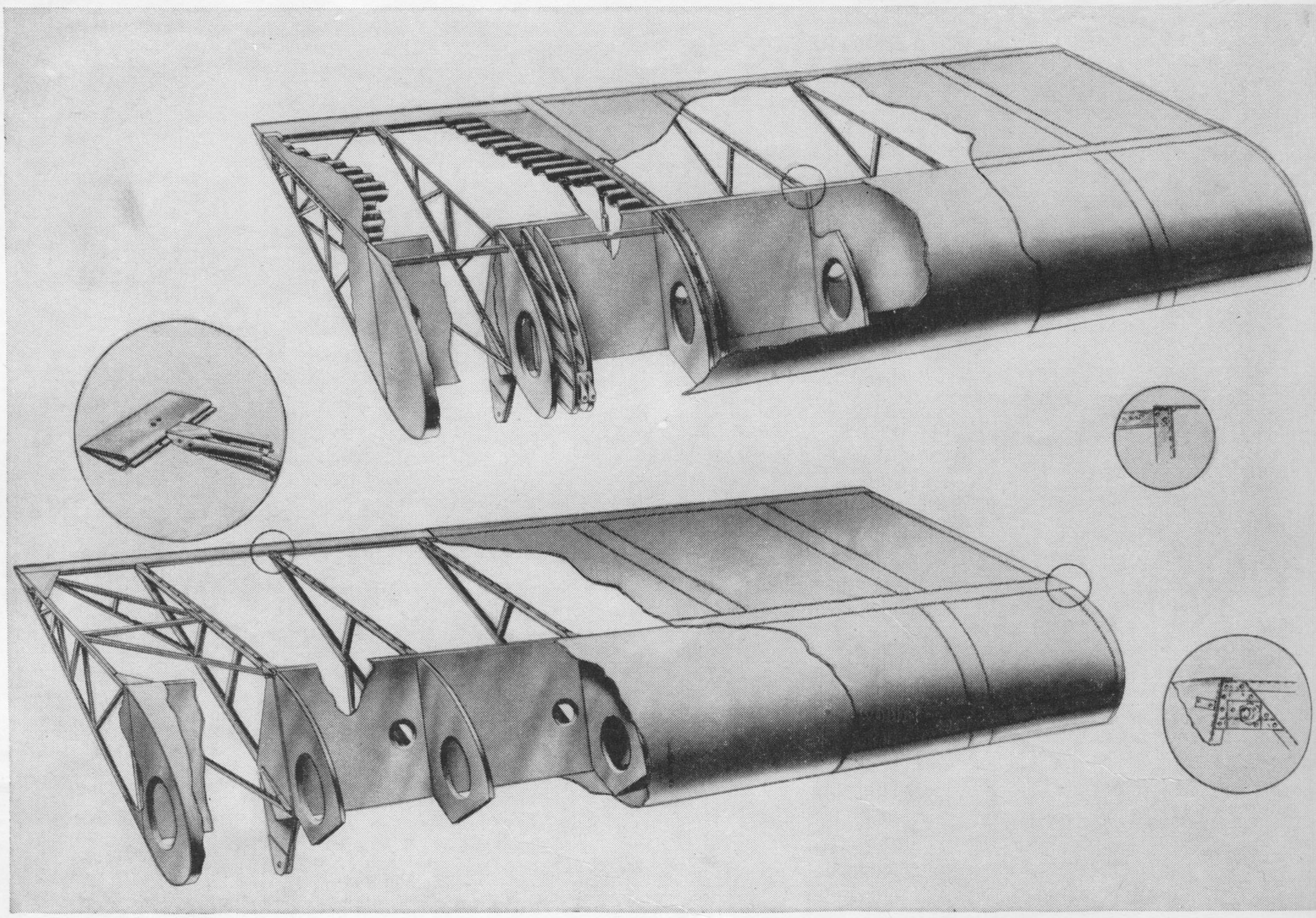


Fig. 3. The flaps are built in same manner as the ailerons, with corrugations under the walkway. The covering is 12 oz. duck over a stainless-steel frame.

Focke-Wulfe FW-190

Built as a single unit from tip to tip, the FW-190 wing (1) departs from the conventional construction. Thus, if it is damaged structurally at any place between the detachable tips, the entire unit must be replaced.

As it takes the combined weight of the two lower side and bottom engine mounts, fuselage fitting attachments, four 20-mm cannon, and the main landing gear, the integral center section of the tapering front spar is a very heavy member. At the center line it is a built-up triple-web I beam 16¾ in. deep, reinforced by a heavy vertical channel-shaped member embracing, at its lower end, a forged fitting for the lower engine mount structure, a combined tubular and channel truss unit (2). Between the center line and the side engine mounts, set 24 in. out, are two vertical hat-shaped stiffeners. Engine mount members themselves are of similar shape but are heavier and riveted rather than bolted to the spar.

The spar is bent forward 14 deg at these side engine mounts, the angle being maintained 64½ in. to the main landing gear fittings, from which point it parallels the center section. The bend permits the landing gear wheel to retract in and up ahead of the spar. This section of the spar has, in addition to the cannon ports, three lightening holes and three vertical-angle stiffeners.

The triple-web construction continues beyond the bend to just outboard of the port for the barrel of the inboard cannon. Immediately outboard of the landing gear fittings, where the spar again bends, it is reinforced by a heavy riveted gusset extending some 12 in. beyond the outboard cannon port, from which point to the tips, the spar is a single-web I beam with 1½-in. lightening holes. For the full length of this outer portion, the spar has lips top and bottom to which the leading edge is screwed.

From engine cowl outboard to the landing gear, the L.E. (4) is built as one unit and is attached by screws to the spar. The main member, just outboard of the gun port, is a double-stamped, flanged rib with cutout for the landing gear strut. Two feet farther out is another contour rib of I-beam construction, and between them a stamped, flanged upper contour rib. The tip end of this section also has a stamped, flanged rib with cutout for the landing gear strut. The remainder of the L.E. is built as one unit, consisting of formed aluminum sheet reinforced by conventional stamped flanged D-type nose ribs.

Only five 'tween-spars ribs on each

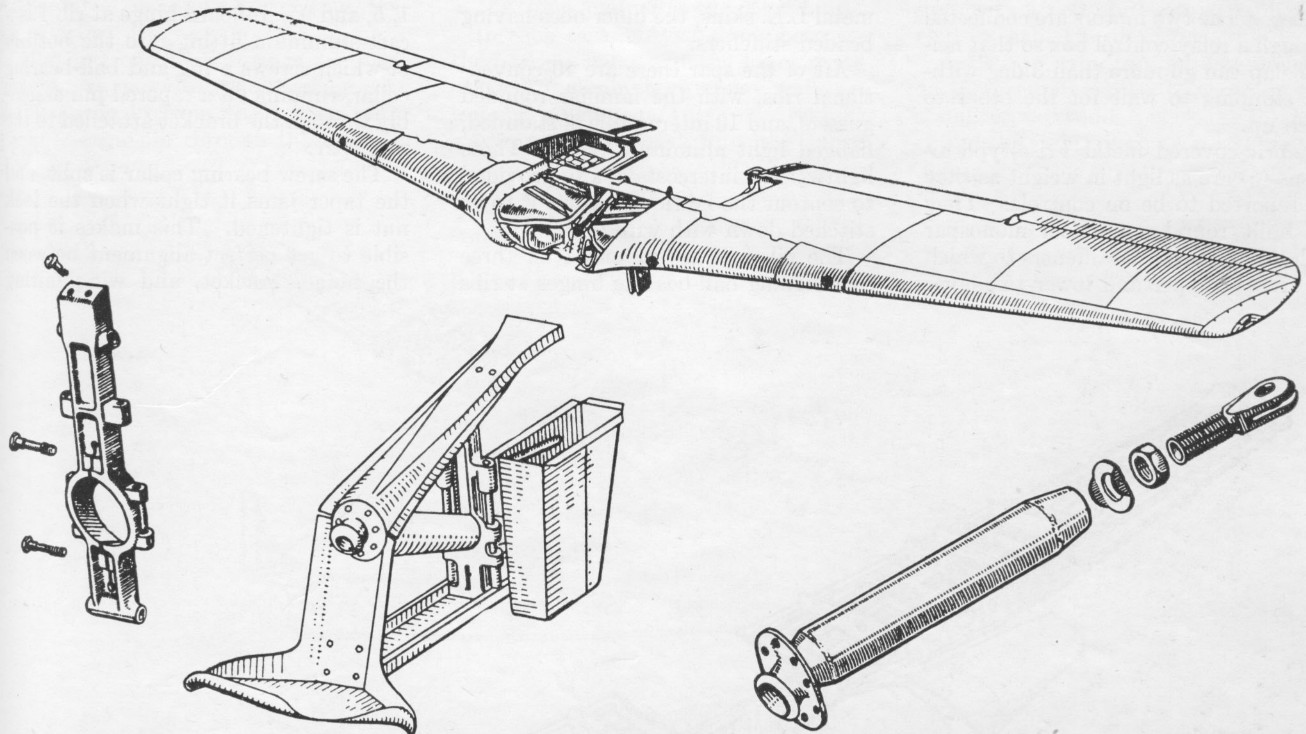


Fig. 1. Full cantilever wing on Focke-Wulfe FW-190 is built around the front spar, which extends through the plane from tip to tip just below the fire wall. It carries a bottom engine-mount support, shown here in a detail sketch. The inner section of the L.E. is built as a separate unit having its own ribs. The outer section, with conventional D-type ribs, is attached by flush screws to lips extending out from the front spar.

side, besides those at the wing tips, are attached to both top and bottom skins (3). Of conventional stamped, flanged construction, they are located just outboard of the inboard cannon; on either side of the landing gear fittings to form a torque box; on either side of the outboard cannon ports; and at the outer end of the reinforcing gusset around these ports.

A conventional tapering I beam, the rear spar extends from top and bottom forged fuselage attachment fittings to the tips and carries both flaps and ailerons. It is double web for 32 in. from the fuselage fittings, single from there to the tips.

Rear spar and top skin panel (forward to the front spar) are built as an integral unit (6), with blind riveting being necessary only for attaching the five top-to-bottom or "solid" ribs previously mentioned. Three stamped, flanged contour ribs are located between the solid ribs, and six are utilized between the outer flap hinge and the tip rib. All these ribs have cutouts for Z-shaped spanwise stringers, of which there are nine outboard of the flap, and eleven between the solid ribs. The skin after the rear spar, above the flap, is a separate subassembly attached by 10 contour ribs riveted to the spar web, with one continuous stringer between the spar and the trailing edge.

Also built as a unit is the bottom skin panel, which screws to front and rear spars. One contour rib is located at the fuselage attachment fitting, one between the cannon and landing gear ports, and five between the outer "solid" rib and the tips. All these ribs have diagonal cutouts for Z-shaped stringers similar to those in the upper panel.

An interesting development found in the later 190 models is the addition of aluminum strips, 0.032 in. thick and ¾ in. wide, riveted to the ribs and skin, much like diagonal braces between joists in a house to prevent side sway. This addition has been made to both top and bottom skin panels and appears to be a modification made in production rather than in the field.

The flaps are of split type and follow conventional practice, with the monospar being made up of a rolled section with beaded stiffeners (8). The top skin section is cut out in the familiar rounded gusset pattern; ribs are normal stamped, flanged construction. Top and bottom sections are riveted together at the L.E., and the whole is fabric-covered.

With a total span of 7 ft 10 in. each, the flaps are built up in halves, the two sections being riveted together adjacent to the middle of three ball-bearing hinges. Atop the T.E. are ten ½ in. diameter rubber bumpers to absorb vibration between the flap and the T.E. (7).

Inboard and outboard hinge fittings are castings riveted to the flap spar. The mid-fitting, which also forms the flap-actuating arm, is of built-up welded construction. Attached to this fitting is a dial reading from 0 to 60 deg, visible through a hole in the top skin panel, so that the pilot can get an exact reading of each flap position.

Flaps, driven electrically by gear trains through a nut to a screw jack attached to the motor mounted on the front face of the rear spar, move down

60 deg. The two motors are connected through a relay control box so that neither flap can go more than 3 deg without stopping to wait for the other to catch up.

Fabric-covered metal Frise-type ailerons (5) are as light in weight as they are reported to be on controls. They are built round a channel monospar with beaded vertical stiffeners to which are riveted upper and lower two-layer metal L.E. skins, the inner ones having beaded stiffeners.

Aft of the spar there are 10 conventional ribs, with the familiar rounded gussets, and 10 intercostals of stamped, flanged light aluminum alloy. These lightweight intercostals are provided to contour the fabric and allow it to be stitched down with wire (9).

The ailerons are mounted on three self-aligning ball-bearing hinges at ribs 1, 5, and 9. Inboard hinge at rib 1 is a cast-aluminum fitting into the bottom of which screws a lug and ball-bearing collar, running on a tapered pin assembly through the bracket attached to the rear spar.

The screw bearing collar is split, and the taper jams it tight when the lock nut is tightened. This makes it possible to get perfect alignment between the hinge, bracket, and wing fairing

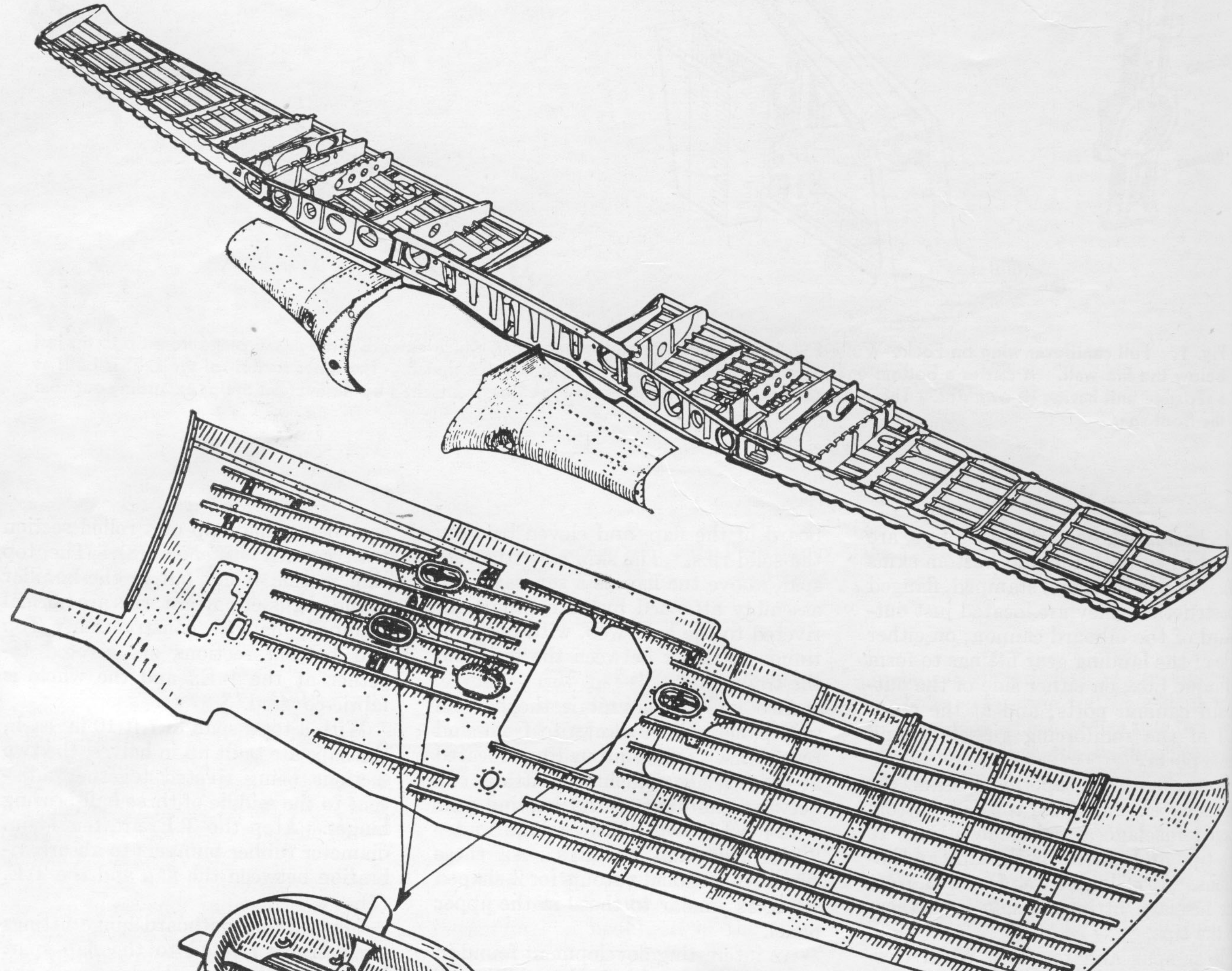


Fig. 2. Front spar at center line is $16\frac{3}{4}$ in. deep, with triple-web construction extending out beyond the inboard gun ports and double-web to a point beyond the outboard gun ports, from which point it is conventional single-web I beam. The lower skin, with ribs, stringers, and inspection panels, is made up as a separate subassembly and attached as a unit to the spar. A joggle in the spar is deep enough so that the landing gear wheel is in front of it when retracted.

without the necessity of mating the parts in jigs.

Mid and outboard fittings are cast angle brackets, with roller-bearing collar screwing in from the bottom and running on a pin through the bracket in the same manner as the other hinge.

In each case, curved shims between the bearing collar and the bracket are utilized to eliminate side play while retaining alignment. Balance weight washers are fastened into the hinge slots with a bolt and captured nut riveted to each side rib of the slots.

A 19¼-in. trim tab, adjustable only on the ground, similar to those on the stabilizer and rudder, is on the inboard end of the right aileron.

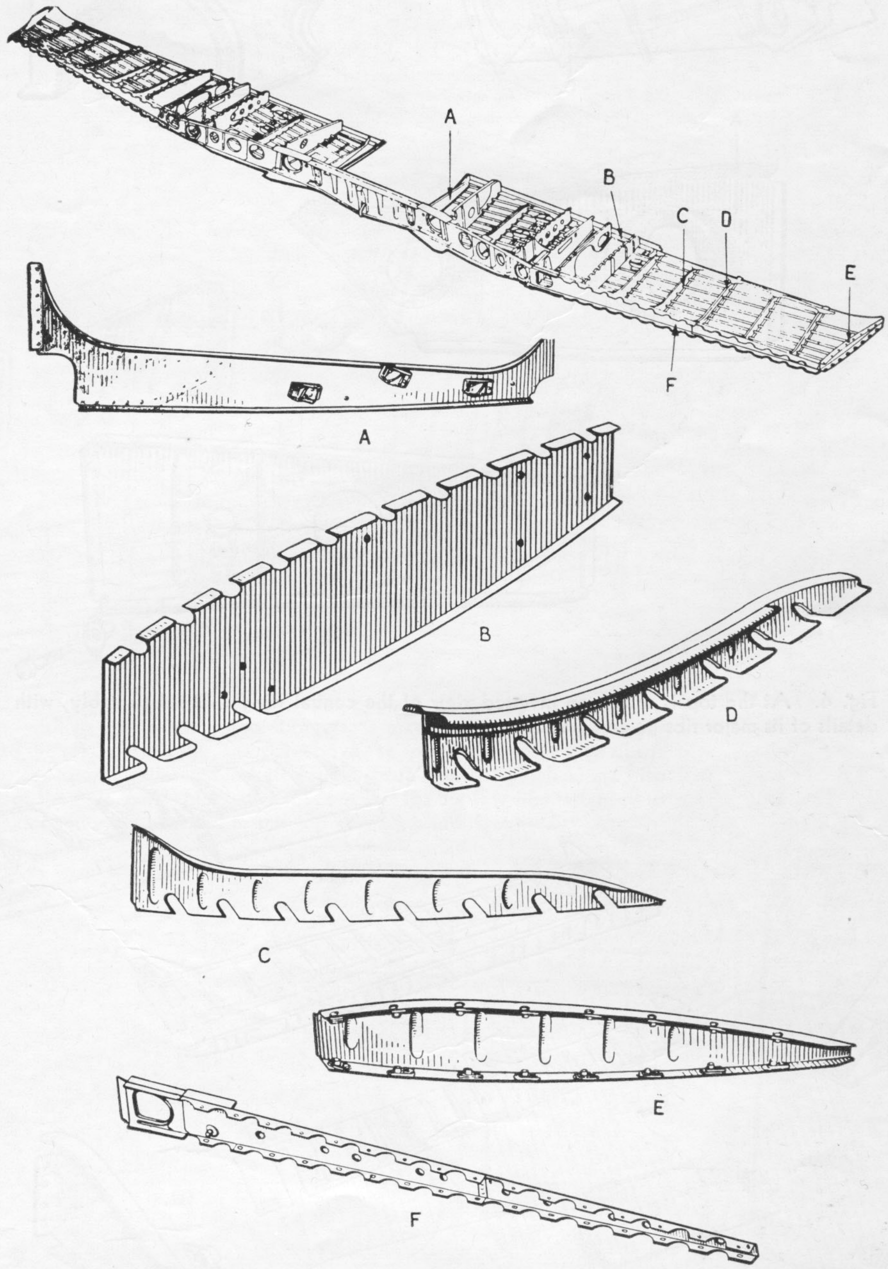


Fig. 3. Wing ribs of the FW-190 vary in construction, and only five are attached to both top and bottom skins. Top detail sketch *A* shows a rib adjacent to the fuselage, with reinforcement forgings; *B* is the outboard-most "solid" rib; *C* and *D* are typical floating ribs; *E* is an outboard rib to which formed tips are attached with flush screws. *F* illustrates the construction of the spar from the outboard cannon port to a wing tip, showing forward-extending lips, to which the L.E. is screwed.

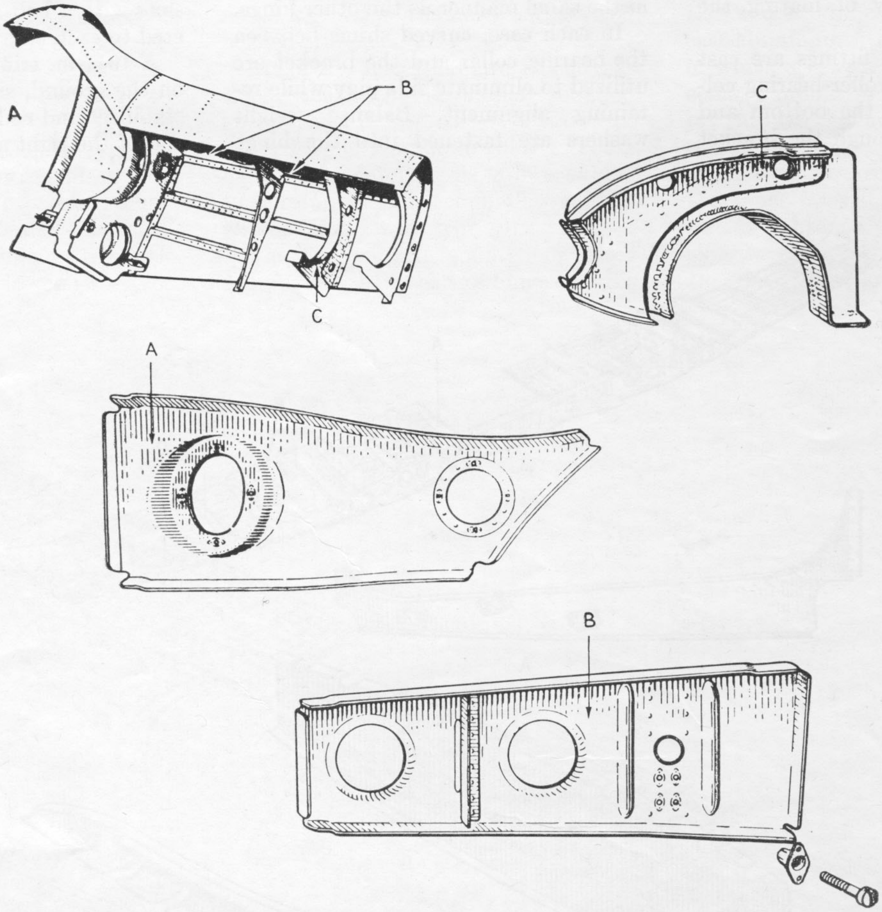


Fig. 4. At the top is shown an inverted view of the central wing L.E. subassembly, with details of its major ribs given below.

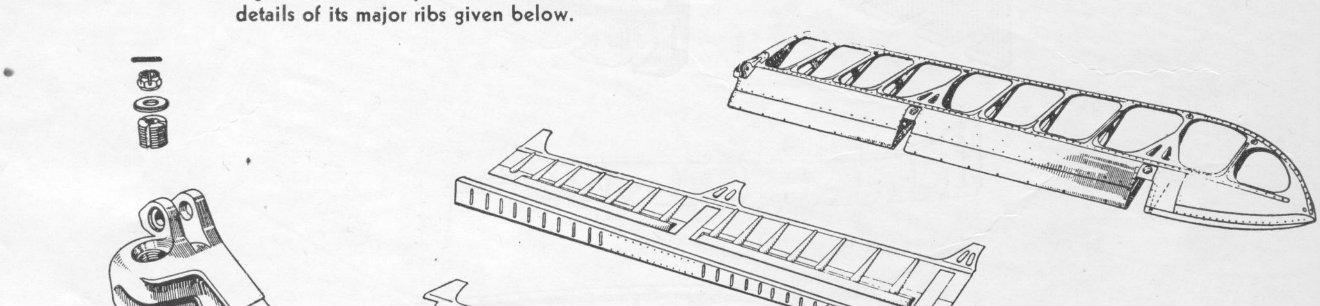


Fig. 5. Complete details of the aileron are shown from top to bottom: unit without fabric covering; lower L.E. skin; single spar; upper L.E. skin; unit with fittings and fabric covering in place. At the left is an exploded view of the inboard ball-bearing mounting; at the extreme right is an exploded view of the outboard hinge slot ribs.

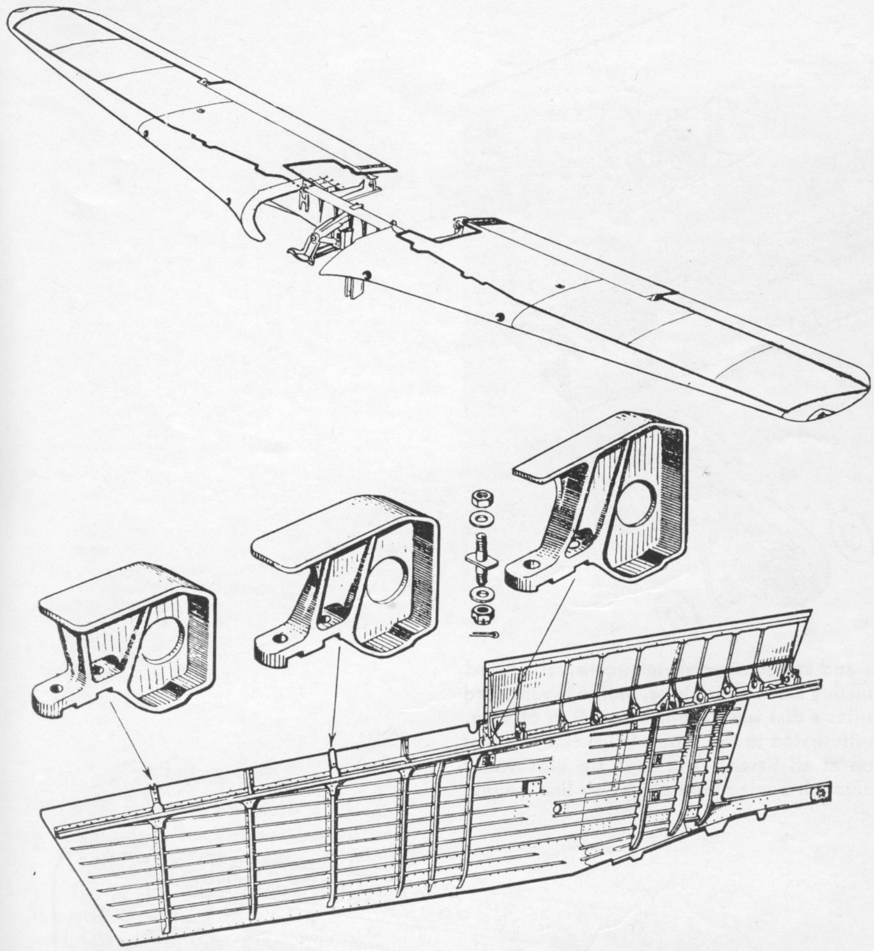


Fig. 6. The top skin, with its floating ribs and stringers, is made up as a complete subassembly and riveted to the rear spar; finally, the skin above the split-type flap with its ribs is attached to the rear of the spar. Aileron brackets (shown in the detail sketches) are also riveted to the aft face of the rear spar. Note that space is left for the few ribs fastening to both top and bottom skins; they are attached to this top skin by blind riveting.

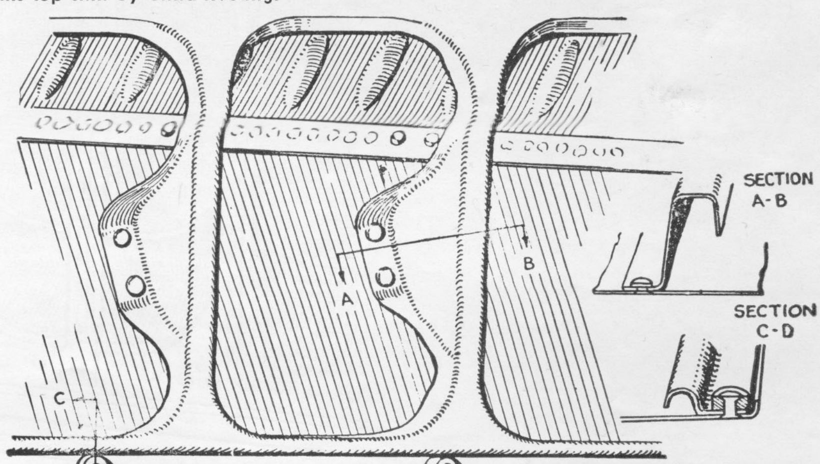


Fig. 7. Detail of a flap from above, with the top fabric covering removed to reveal how the ribs are formed from cutout sections of the top face. Shown on the T.E. are 2 of 10 rubber bumpers which absorb vibration when the flap is closed up against the top skin.

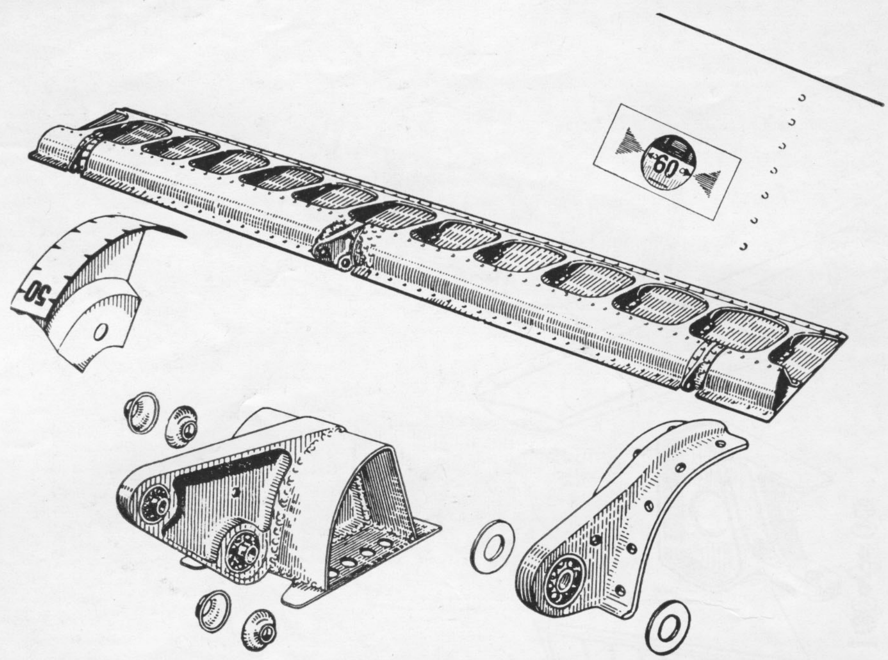


Fig. 8. Flaps are built around a metal monospar and are constructed in two halves riveted together at the middle hinge, with inclusion of actuating arm. This hinge, unlike the inboard and outboard hinges, is welded to the spar and carries a dial with readings from 0 to 60 deg. Numbers show through a hole in the top skin (as illustrated in the top detail sketch) so that pilot has an exact reading of each flap's position at all times. The flaps are electrically operated with their individual motors connected through a relay control box so that neither will get more than 3 deg out of line with the other.

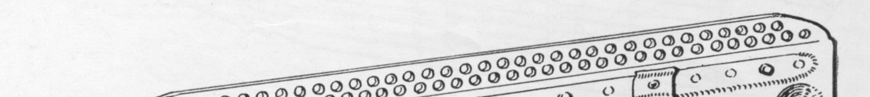
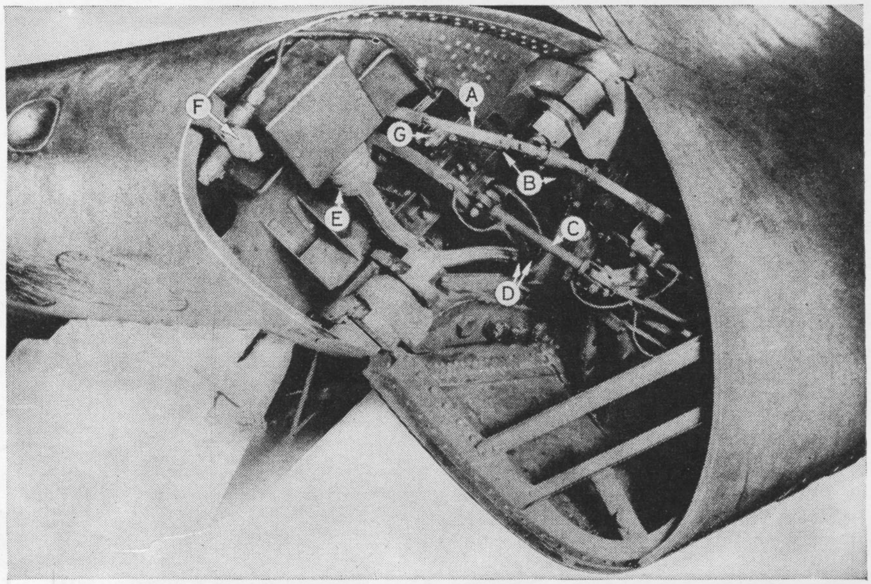


Fig. 9. Sketch (right) of the inboard end of an aileron with the bottom fabric removed. Intercostals (only 0.012 in. thick) serve only to hold the fabric which is stitched in place with continuous wire fastening poked through the slots punched in the frame. These slots are in a groove so that the wire is buried beneath the fabric surface. Also clearly shown is a perforated trim tab similar to those used on the rudder and elevator.

Grumman F6F

The F6F is provided with a folding wing mechanism for carrier operations (1). Hinge fittings are bolted to the front spar (2). Also attached to the front spar and rib is built-up landing gear support structure.



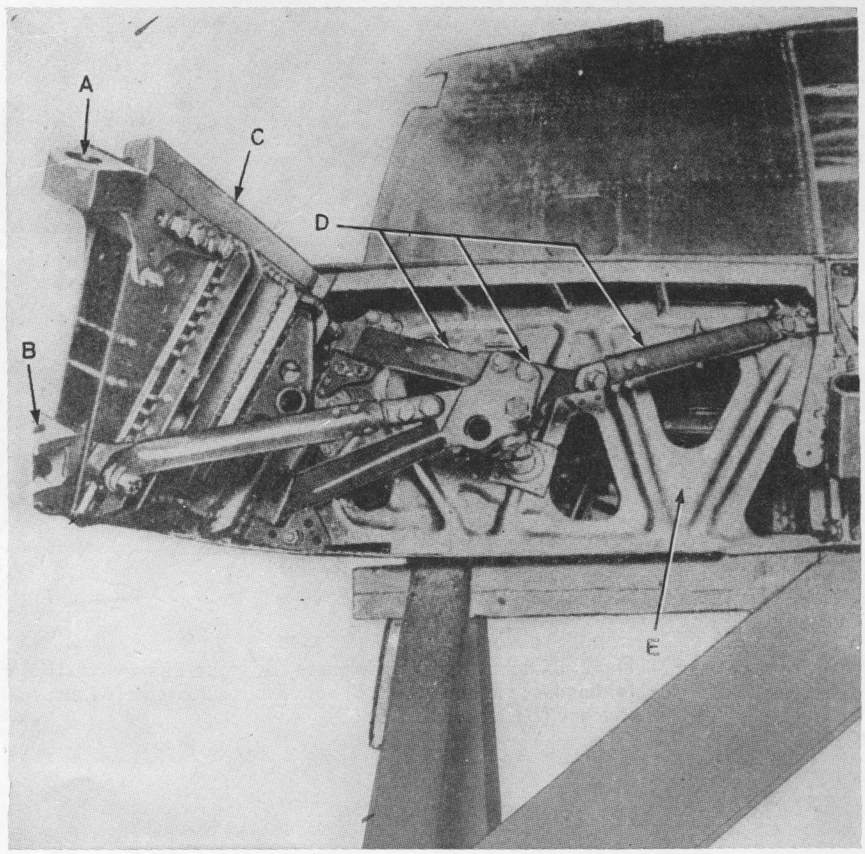


Fig. 1. Left wing-folding axis of Grumman F6F, with leading edge of wing center section at *A* and upper and lower hinge points at *B* and *C*, respectively. *D* is the aileron tab-control connecting link, *E* is a tab-control link guide cable, *F* is the aileron-control connecting link, *G* shows the flap-actuating cylinder hydraulic lines.

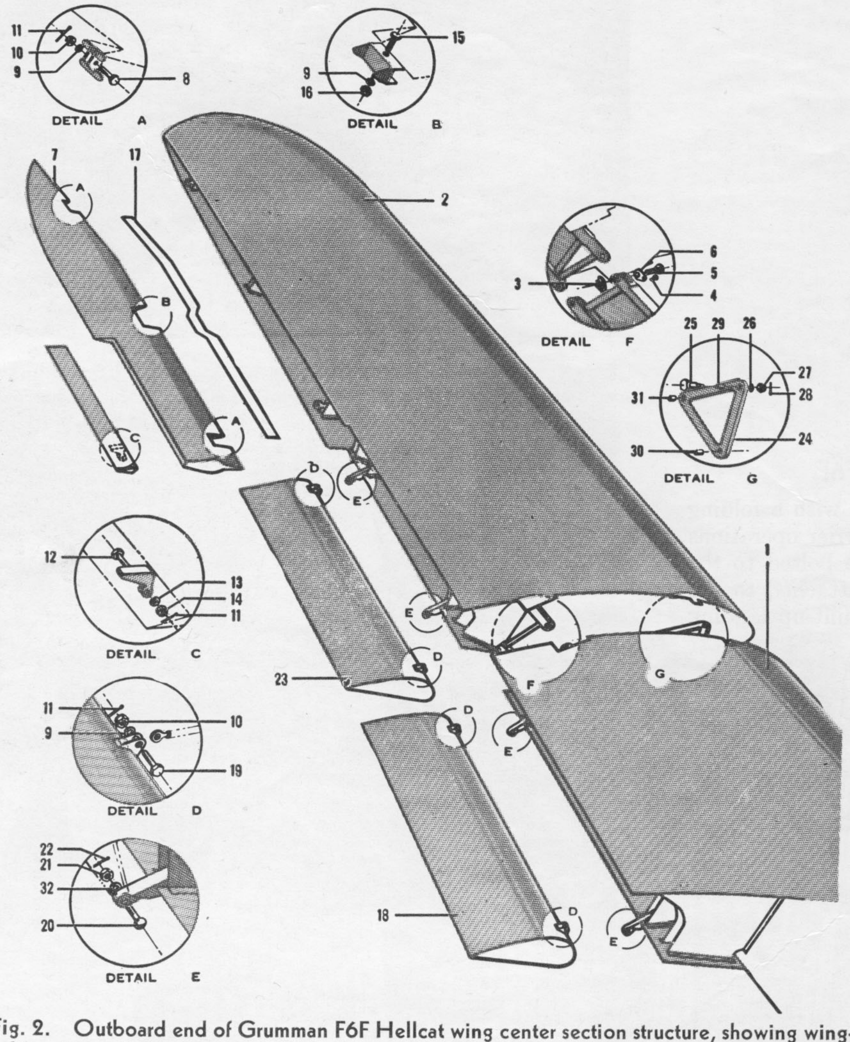


Fig. 2. Outboard end of Grumman F6F Hellcat wing center section structure, showing wing-folding hinge fittings (*A* and *B*) bolted to the front spar (*C*), also built-up landing gear support structure (*D*), and typical rib (*E*).

Ryan FR-1

In the FR-1 wing, all bending stresses are taken by the single spar, and torsion by the skin, with ribs serving only to support skin contour to prevent buckling (1).

The principal design problem involved in the center wing section (3) was to obtain adequate strength and at the same time to allow sufficient space for large air intakes in the leading edge (4). Through these ducts, air is led under the cockpit and aft into a plenum chamber forward of the GE turbojet engine mounted in the aft fuselage. In addition, .50-caliber guns are installed next to the intakes, four guns in all being carried by the aircraft.

The aileron comprises a main spar, false spar, extruded-aluminum alloy spacers, stamped ribs, and flush-riveted metal skin (2). The spars are formed of C sections. The ailerons are hinged at three points; the trim tab by a continuous hinge.

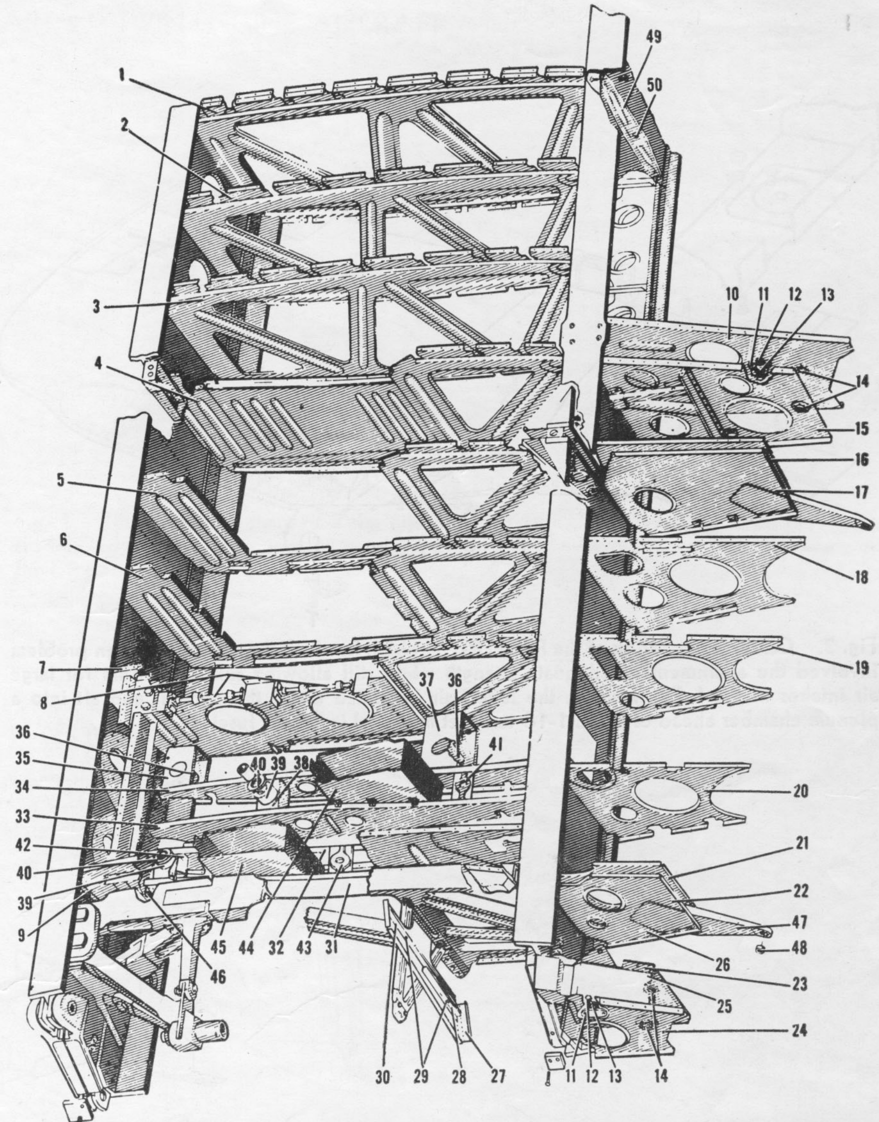


Fig. 1. Exploded view showing the major components of an FR-1 Fireball wing, a shell-type structure in which all bending stresses are taken by its single spar, and torsion by the skin, with the ribs serving only to support the skin contour to prevent buckling.

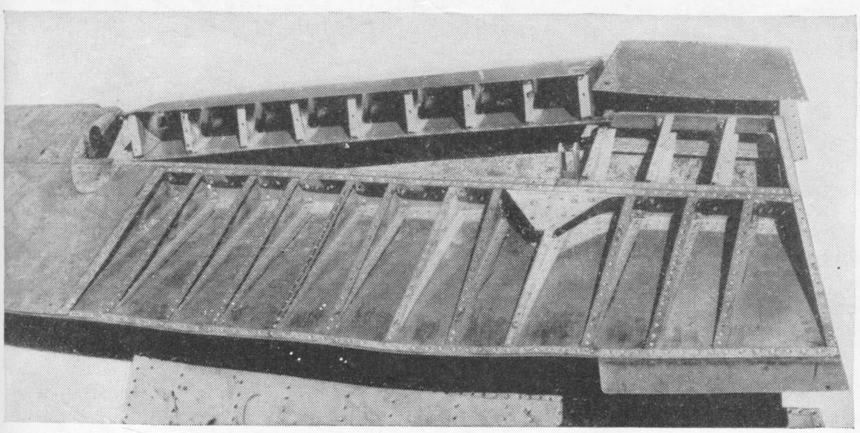


Fig. 2. The Ryan FR-1 Fireball aileron.

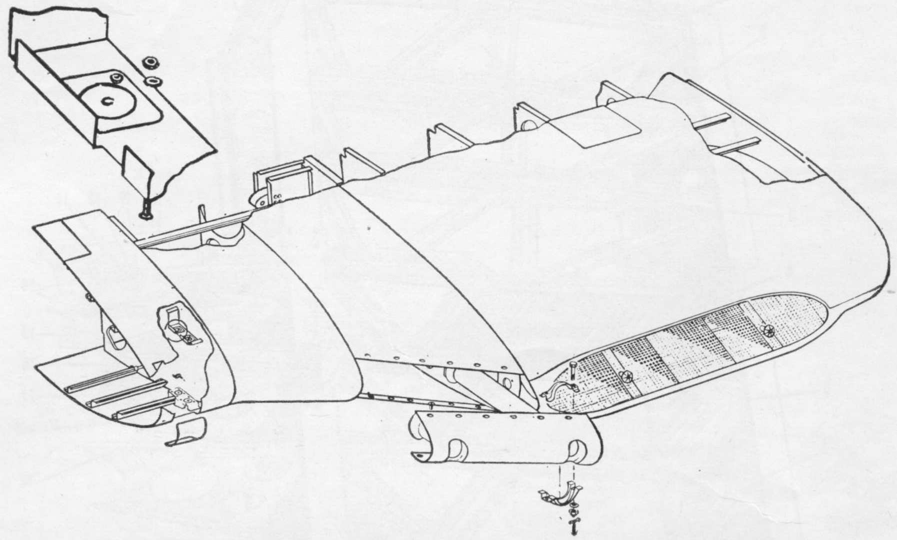


Fig. 3. Center wing section of the Ryan FR-1 Fireball, in which the principal design problem involved the attainment of adequate strength while still allowing sufficient room for large air intakes in the L.E. Through the latter, air is ducted under the cockpit and aft into a plenum chamber ahead of a GE 1-16 turbojet mounted in the aft fuselage.

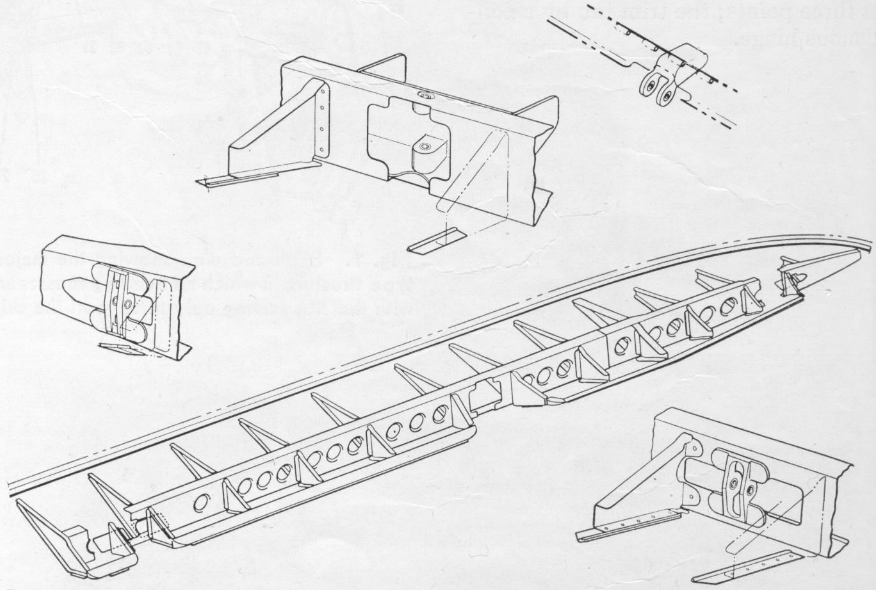


Fig. 4. Section of the right wing of a Ryan FR-1, depicting air intake for the turbojet. Just to the left of the intake, the L.E. skin has been removed to show the installation of two of the craft's four .50-caliber machine guns.

Martin 2-0-2 Transport

The Martin 2-0-2 is mathematically developed to provide a high lift coefficient with low drag at all operating speeds. A Martin-developed slotted aileron (1) produces a high rate of roll with much less than the conventional aileron area, permitting larger flaps to provide extra useful lift.

The hydraulically operated flaps are double slotted, and so arranged as to produce high lift with low drag in the take-off position, and high lift with high drag in the landing position (2). In normal flight position they fair in as an integral part of the wing, lowering the drag at high speeds. Brush seals on the ends of the flap shutter door (3) are used to seal the gap between it and the flap hinge fairing. When the flap is retracted and the shutter door closes the gap, a slat armhole in the door is sealed by a rectangular fairing block for better streamlining (4).

The wing tips are detachable and also interchangeable, thus simplifying maintenance.

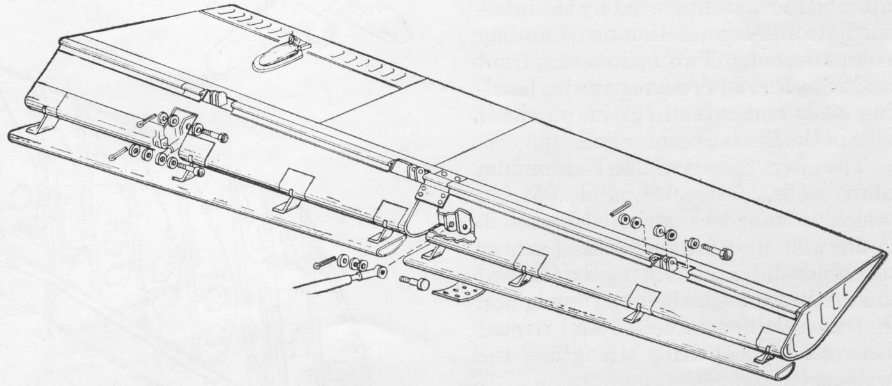


Fig. 1. The feature of the van Zelm aileron, seen here, is the auxiliary vane below the leading edge, which functions to produce smooth flow over the lower aileron surface in the UP position.

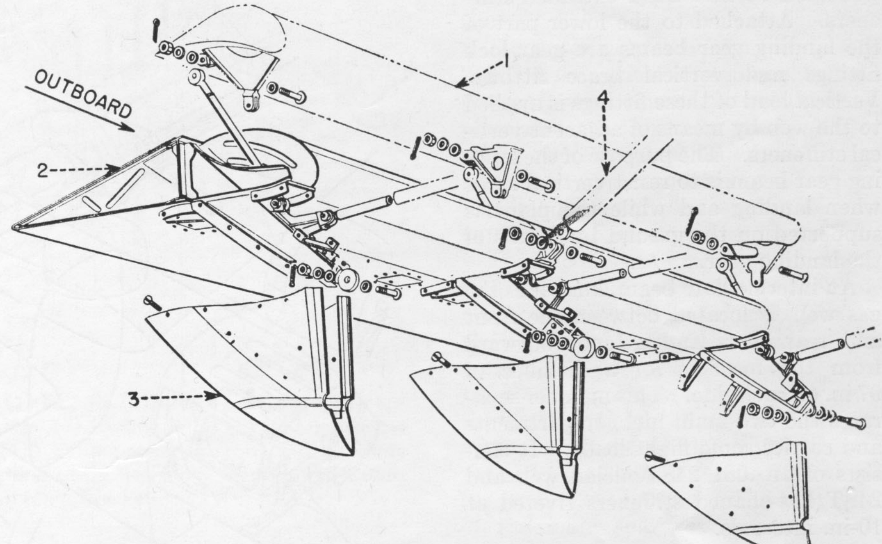


Fig. 2. Inboard wing flap installation: (1) vane; (2) flap; (3) hinge fairing; (4) screw jack.

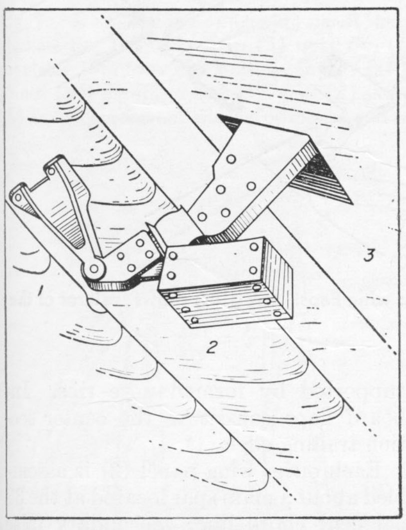


Fig. 4. Even small details receive attention. When the flap is retracted and the shutter door closes the gap, a slat armhole in the door is sealed by a rectangular fairing block for better streamlining. Shown are: (1) flap; (2) slat; (3) shutter door.

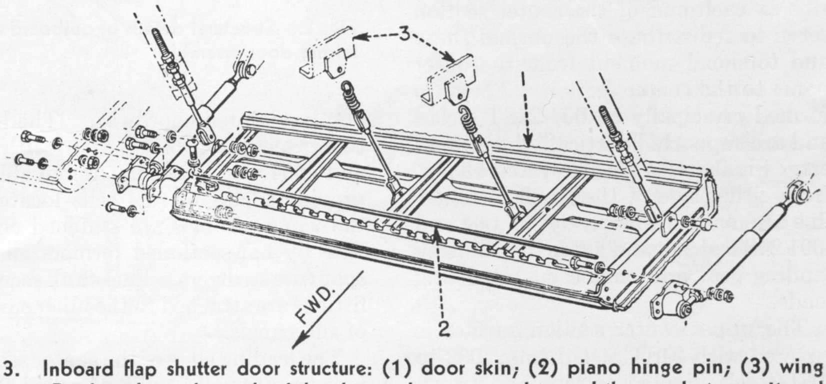


Fig. 3. Inboard flap shutter door structure: (1) door skin; (2) piano hinge pin; (3) wing formers. Brush seals on the ends of the shutter door are used to seal the gap between it and the flap hinge fairing.

North American B-25 Mitchell

The center wing section of the B-25 is attached to and supported by the intermediate fuselage section or bomb-bay compartment. Two main spars, front and rear, serve to resist spanwise bending loads and extend 157 in. on either side of the fuselage center line.

The spars consist of 24ST aluminum alloy webs, .081, .064, and .051, to which extruded capstrips are riveted. A fire wall of .019 stainless steel acts as a doubler and extends along the forward side of the front spar behind the engines. Extruded stiffeners bolted and riveted between the capstrips strengthen the webs.

Landing gear beams between the front and rear spars begin at a point 97 in. from the center line to the fuselage and consist of .051 24ST alclad webs and vertical 24ST extruded stiffeners. Attached to the lower part of the landing gear beams are gear lock fittings and vertical brace fittings. Vertical load of these fittings is applied to the web by means of adjacent vertical stiffeners. The purpose of the landing gear beam is to resist vertical loads when landing and while the plane is supported on the ground by means of the landing gear.

An intermediate beam, known as the gas web, is located between the front and rear spars and extends outward from the fuselage for a distance of 97 in. on each side. This member separates the two main fuel compartments and carries some flight loads. It consists of an .081 24ST alclad web and 24ST hat-shaped stiffeners riveted at 10-in. intervals.

Six center section ribs distribute a major portion of landing gear fitting, major gear beam, and engine mount fitting loads. Wing-joint plate-type ribs at each end of the center section serve to redistribute the normal shear and torsional moment from the outer panel to the center section. They are formed principally of .064 24ST alclad and are supported vertically by stiffeners. Similar ribs placed 97 and 133 in. from either side of the fuselage center line are made, respectively, of .064 and .091 24ST alclad and aid in distributing landing gear and engine mount fitting loads.

The upper center section surface is covered with 24ST alclad from .032 to .081 thick, riveted to ribs and transverse stiffeners, butt-jointed spanwise,

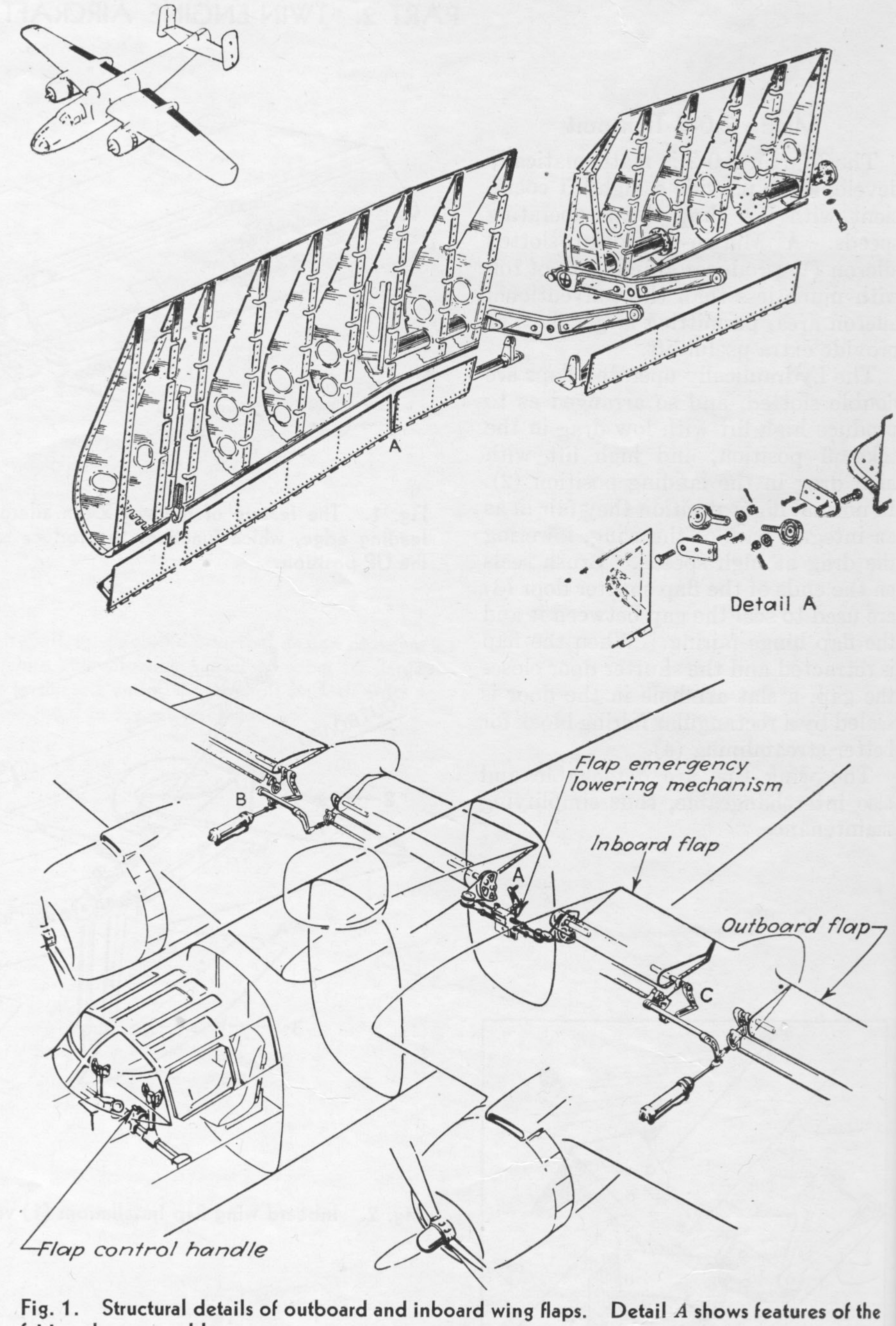


Fig. 1. Structural details of outboard and inboard wing flaps. Detail *A* shows features of the fairing door assembly.

and lap-jointed chordwise. The lower center section surface is fitted with .051 and .064 24ST panels, removable to provide access to fuel cells located in the wing. Panels are stiffened chordwise by hat-sectioned formers and by spanwise stringers. Fuel-tank securing fittings are attached to the inner surface of the panels.

The leading edge of the center section is conventionally built of rolled 24ST alclad skin stiffened by stringers and supported by formed nose ribs. Inboard flaps constitute the center section trailing edge (1).

Each outer wing panel (2) is assembled about a main spar located at the 33 per cent chord line. Secondary false spars extend the length of the panel along its T.E. The remaining structure consists of ribs pressed from 24SO and 24ST alclad sheet, extruded spanwise stringers, and 24ST alclad skin. Access and inspection doors are pro-

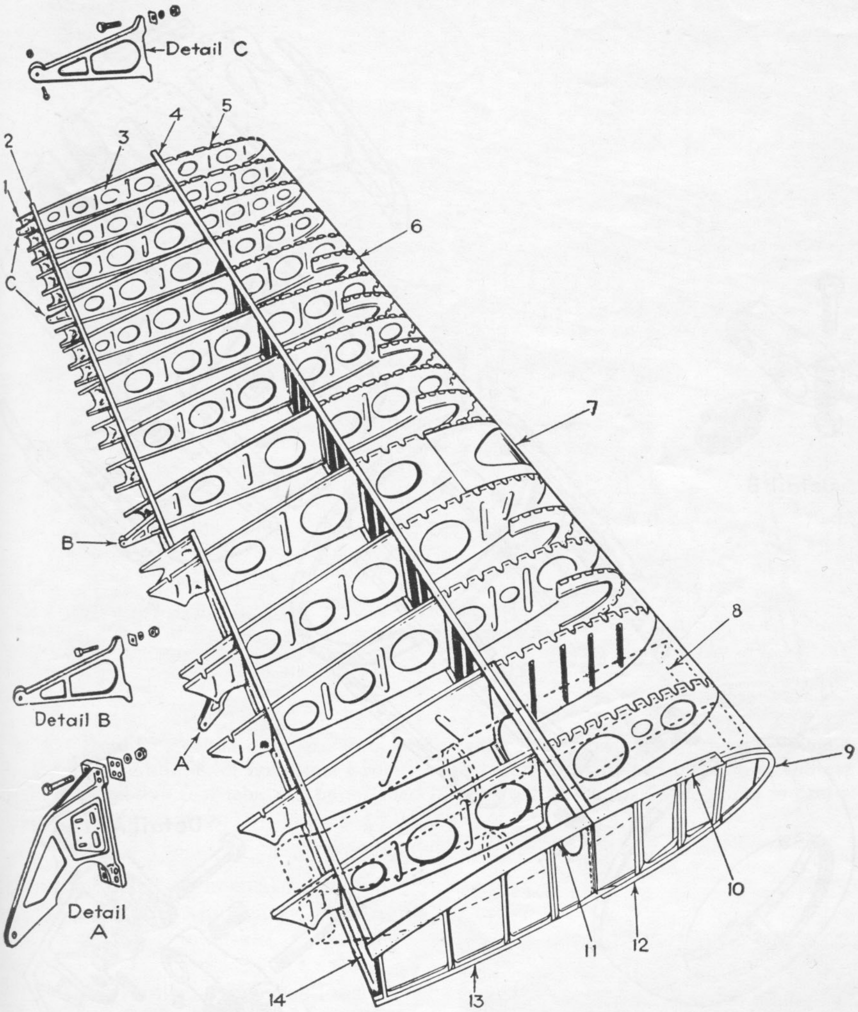


Fig. 2. **Details of the outer wing panel structure: (1) T.E. rib; (2) aileron false spar; (3) intermediate rib; (4) main spar; (5) nose rib; (6) former; (7) landing light; (8) oil-temperature regulator location; (9) bolting angle; (10) to (13) bolting-angle supports and attaching joints; (14) flap false spar. Detail (*A*) shows features of the flap hinge bracket, and details (*B*) and (*C*) represent aileron outboard and inboard hinge brackets.**

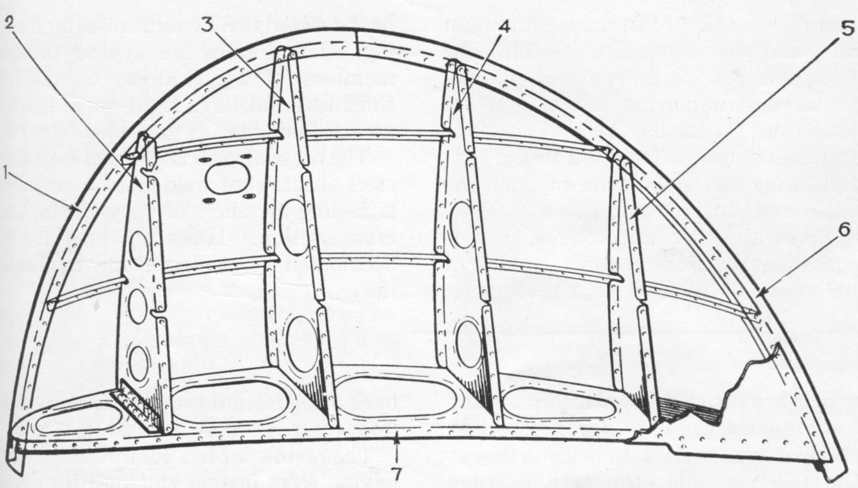


Fig. 3. **Structural features of the wing tip; (1) forward bow; (2) front former; (3) and (4) front and rear intermediate formers, respectively; (5) rear former; (6) rear bow; (7) rib.**

vided along the entire wing, most being on the lower skin.

The outer main wing spar consists of inboard and outboard sections of 24ST sheet splice with an .064 alclad doubler plate. The inboard spar section is .081 material formed with upper and lower U-shaped flanges serving as spar caps. The web is stiffened by a vertical rib attaching right-angle extrusions and independent stiffener angles.

Outboard of the wing center section attaching plates, the web is cut away to permit installation of two oil-cooling ducts. Each cutout is reinforced by a T-section extruded ring riveted around the cutout. The inboard spar section is additionally reinforced by an .081 24ST alclad doubler extending between the ribs on either side of the cutout. The outboard flanged web is .064 alclad with the upper and lower edges formed to provide spar caps. Eight flanged lightening holes are provided in the spar tip.

The outer wing flap false spar is .040 24ST alclad with formed right-angle flanges for spar caps. Between the end plate and the third rib, the spar of a single sheet of .040 24ST section is riveted to upper and lower spar caps. The inboard web section has several cutouts to accommodate equipment.

The ailerons are supported by a false spar of a single sheet of .040 24ST alclad. Formed right-angle flanges on the upper and lower edges provide spar caps. The web is stiffened by several rib attaching angles of extruded alloy arranged vertically along the solid web.

The majority of the wing ribs are pressed from 24ST or 24SO alclad varying from .025 to .040. All ribs forward of the main spar are provided with flanges riveted to the skin. Most intermediate ribs between the main spar and the false spars are formed so they do not contact the skin but are attached to stringers by clips. All ribs are provided with lightening holes and stiffening beads.

The wing tips (3) are built of three ribs and several formers, all press-formed from alclad sheet stock. Beaded lightening holes, stringer cutouts, and flanges are provided in each member. Contour skin is formed from 24SO, and the tips are covered with 24ST alclad and attached to the wing with screws.

On the B-25H and J, wing flaps are the T.E. slotted type, two sections on each side of the fuselage. Inboard flaps extend from the nacelle tail cone

to the fuselage side, and outboard flaps extend from the aileron to the nacelle cone. In neutral position, flaps are sealed by a nonmetallic strip attached to the upper wing surface, and large slot openings on the lower surface of the wing are closed by small fairing doors.

When the flaps are moved to down position, the fairing doors swing upward permitting a flow of air up between the fixed wing and the lowered flap. Rubbing strips of .010 half-hard steel sheet are provided along the flap L.E. at two places. The actuating torque of each flap is taken by a torque tube which extends into its interior. Flaps are supported by, but not hinged to, the torque tube.

Flaps have power-pressed ribs and spanwise stiffeners. Ribs are provided with stringer cutouts and lightening holes. The T.E. is formed of .032 24ST alclad.

Sealed-type ailerons have a front spar and pressed ribs. Conventional weights are attached to the L.E. to obtain static and dynamic balance.

The aileron main spar is 137 in. and is formed from .032 24ST alclad sheet into a U-shaped channel, joggled on the outside upper and lower cap edges to provide for the attachment of fabric replacement strips. Rib attaching angles are placed vertically on the spar web. Lightening holes are spaced along the entire length. A light false spar is provided as a trim tab attaching member. Ribs are formed from .032 24ST alclad and include formed top and bottom frames and beaded lightening holes.

A trim tab, mounted in the T.E. of each aileron, consists of a small metal airfoil of rectangular plan view, having a U-shaped spar, triangular-shaped ribs, and alclad covering. Hinged at three points to the aileron false spar, the tabs serve as control boosters in addition to the trim units and are not balanced.

Engine nacelles are in three main divisions. engine cowling section, front and rear sections. The cowling section consists of a nose ring, cowl formers, and panels (4). Material is aluminum alloy and corrosion-resistant steel. The front and rear sections are of conventional construction and are composed of longerons, stringers, and skin. The front section frames bolted to the bottom wing center section support the entire structure.

Front and rear longerons of the nacelles are rolled Z-section members of .091 and .064 24SO alclad, respectively, heat-treated to ST condition after forming. The frames are typical pressed members of 24ST alclad of varying thickness and have right-angle flanges and stiffening beads for added strength.

The fire-wall web is made of stainless-steel sheet, spot-welded to a series of stiffening members of varying size and cross section. Holes are provided to accommodate electrical and hydraulic lines.

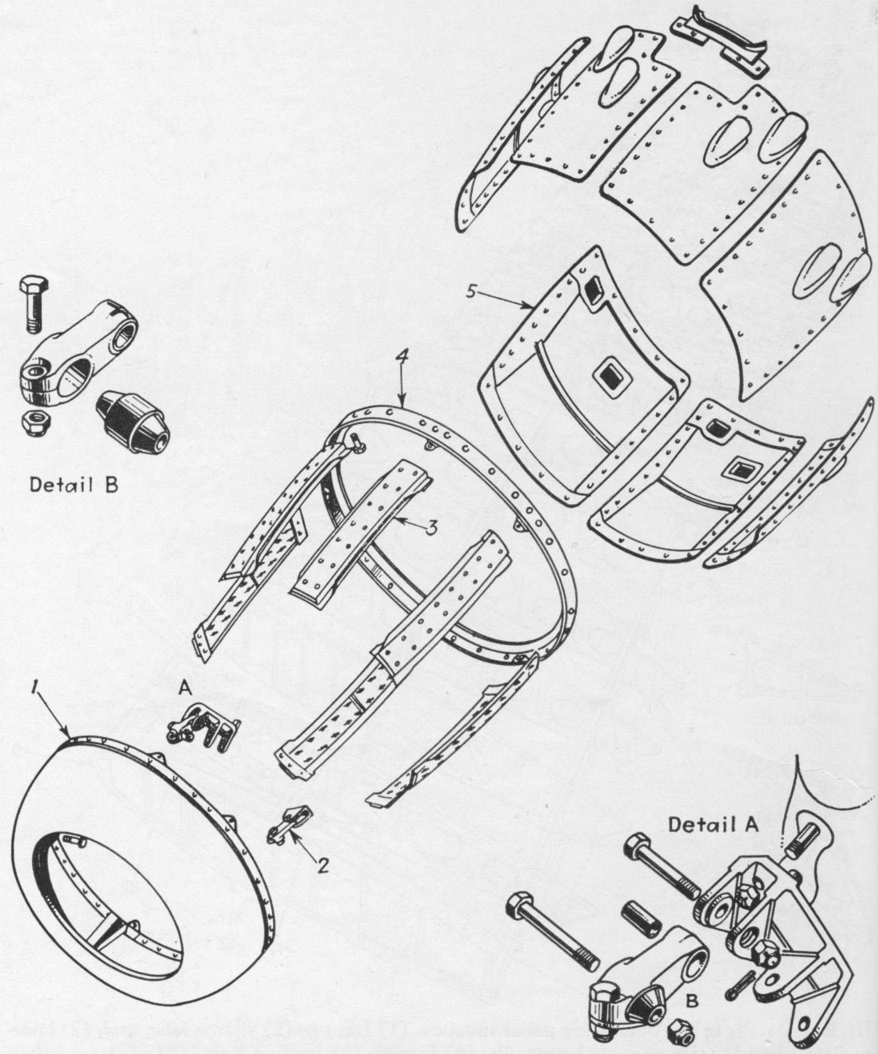


Fig. 4. Nose ring and removable cowling: (1) engine nose ring; (2) link, cowling to engine; (3) cowl former; (4) engine flap ring; (5) removable cowl panel.

Messerschmitt Me-262

Though approximately like our laminar flow airfoils, there are interesting variations in both design and workmanship in the Me-262 jet-fighter wing which has an angular planform. The leading edge has a 20-deg sweepback; the spar sweeps back 12 deg starting at the fuselage side; the trailing edge sweeps forward $8\frac{1}{2}$ deg to the outboard side of the power plant, then sweeps back 5 deg from there on out. In addition, there is 6-deg dihedral.

The main spar is a composite I beam having steel booms and builtup dural web, tapering in depth from $14\frac{1}{2}$ in. at the center line to 3 in. at the tip at-

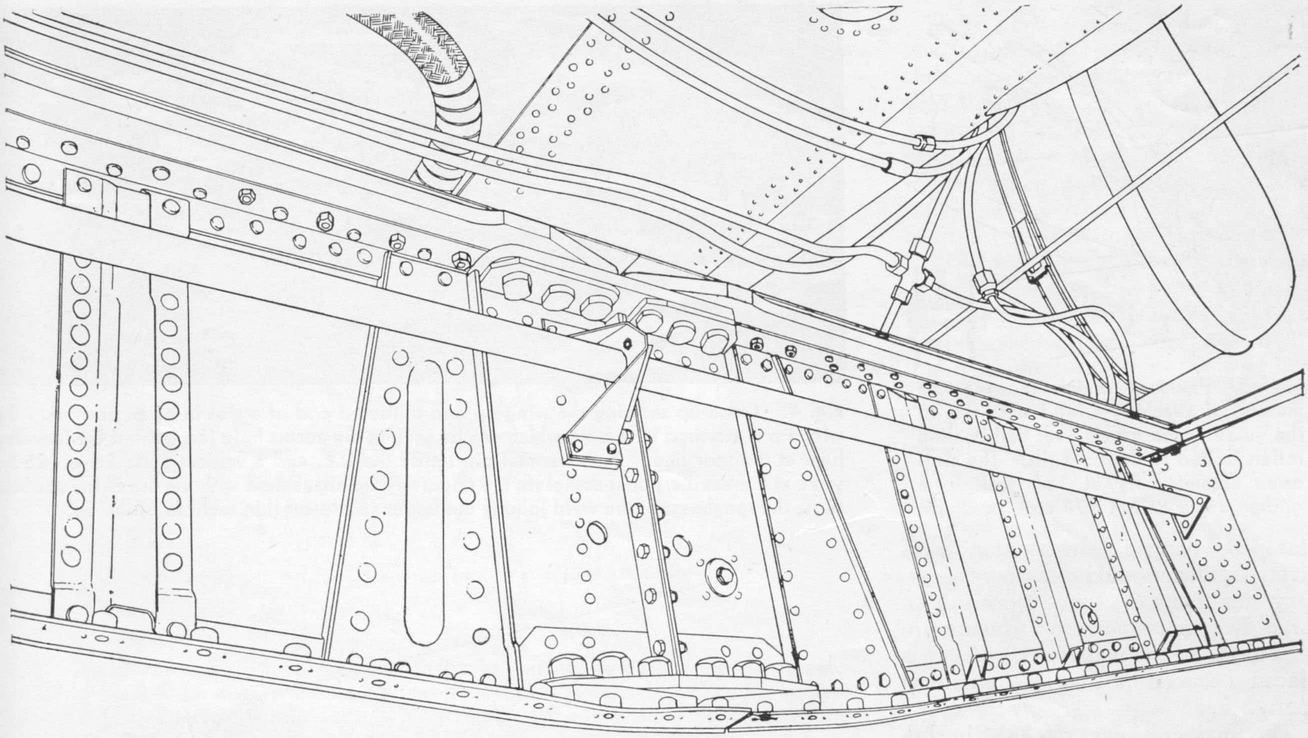


Fig. 1. Front face of the main spar joint at the center line, showing the flanges on aluminum webs bolted together, and steel splice plates on the top and bottom of both steel booms. This particular plane had been flown without the bolts through the splice plates being safety-wired. A reserve fuel tank can be installed just in front of the spar, being held in position through a skin panel screwed to captured nuts (seen on the lower boom).

tachment fitting. The spar boom caps are ¾ in. thick at the center line, the upper being 4¼ in. wide, the lower 4¾ in.

The spar, built in two sections, is spliced at the center line where the webs are flanged and bolted (1). Steel splice plates, ¾ in. thick by 8 in. long, go over both top and bottom of the boom caps and are held in place by six through bolts on each side of the web. None of these bolts, incidentally, was safety wired on one plane that had been accepted by the Luftwaffe. Small steel wedges are placed between the splice plates and lower caps, for the taper on that surface starts right at the center line.

Three heavy steel hat-shaped stiffeners are riveted to the front face of the spar between the center line and the fuselage skin, which is 33 in. away where the spar sweepback begins. Hat-shaped aluminum stiffeners are used from there on out.

Since the spar is at about 35 per cent M.A.C., nose ribs are longer than they would be in a two-spar wing, and consequently vary in construction. Compression ribs have hat-shaped vertical stiffeners, others are of conventional

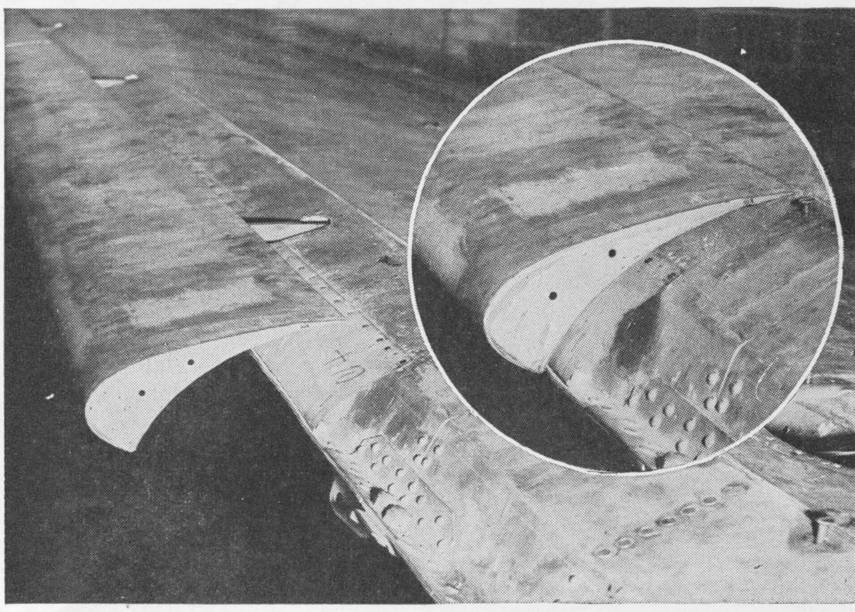


Fig. 2. Detail showing the inboard end of a steel-skinned outer slot in an open position. Note that the L.E. of the wing is of angular shape, with rolled steel sheet riveted to it behind the slot to give the proper airfoil. Inset shows the slot in closed position.

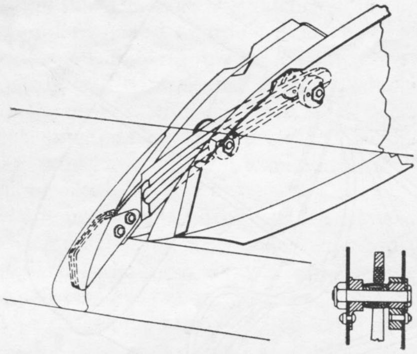


Fig. 3. Phantom sketch showing the method of attaching a full-length slot to the guide which travels over ball-bearing rollers bolted to the nose rib. The slots open automatically at 186 mph in a gliding angle and at 279 mph in climb.

Fig. 4. Close-up showing the wing tip and outboard end of a slot in open position. The wing tip is attached by a bolt, which can be seen in the access hole just behind the formation light at the spar line. A horizontal pin inside the L.E. and a vertical plate fitting into the yoke at the auxiliary spar complete the three-way tip attachment with the use of but one bolt. Note the roughness of the weld joining the upper and lower skin sections of the tip.

stamped, flanged construction with riveted stiffeners and holes where necessary for control connections. Two large J-section spanwise stringers are used ahead of the main spar, and one is placed between it and the auxiliary spar.

The auxiliary spar, set 38½ in. behind the main spar at the center line, is 12 in. deep at that point and is a channel-shaped aluminum structure with hat-shaped stiffeners extending out to the wing tip to carry the flaps and ailerons.

The wing top skin is flush-riveted except at the base of the L.E. where it is flanged out and riveted to the bottom surface. It varies from .083 at the L.E. to .080 at the T.E. At the bottom surface, however, a rolled .010 sheet-steel section is riveted in place to give a true airfoil behind the slots.

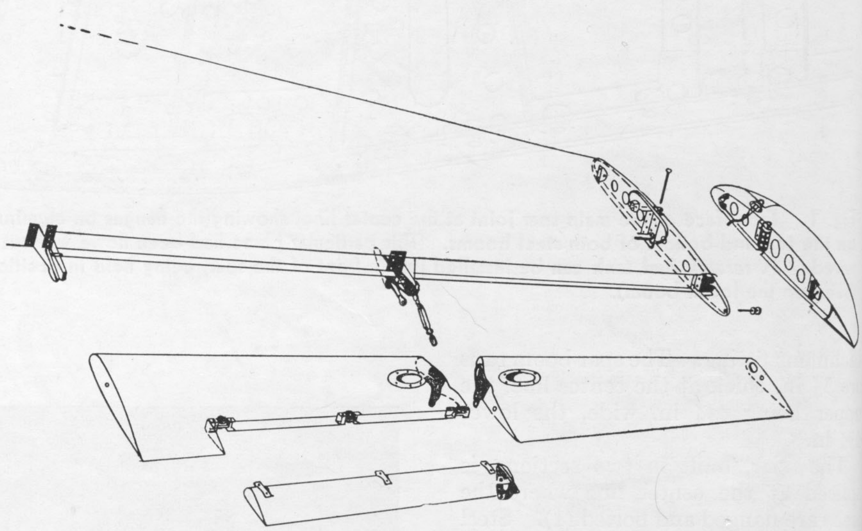


Fig. 5. Exploded view of a wing tip, two-section aileron, and aileron trim tab.

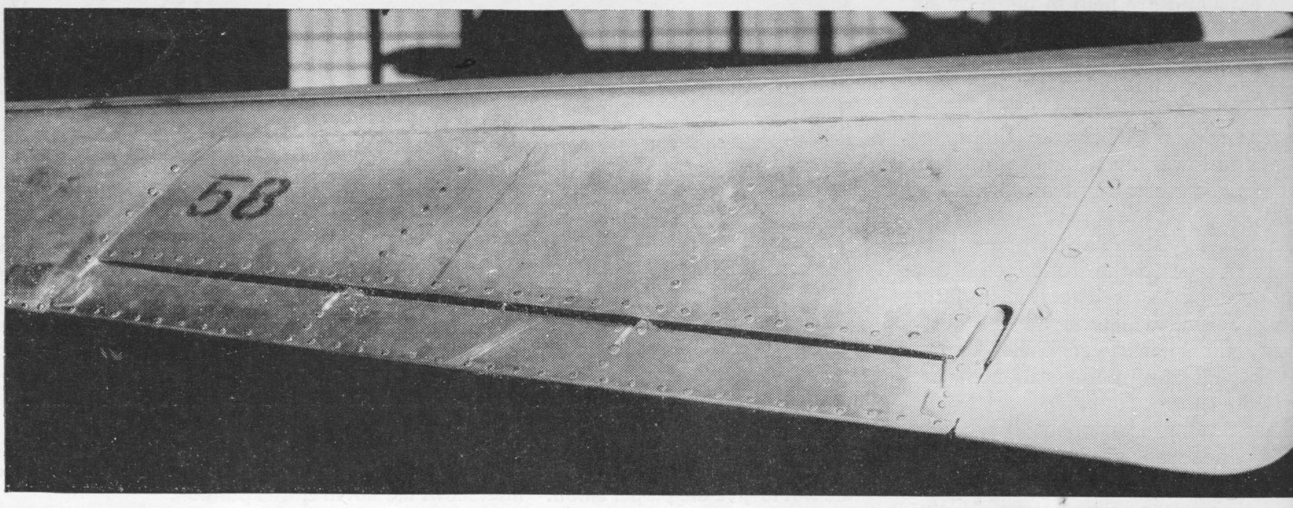


Fig. 6. Detailed photograph of mass-balanced elevator trim tab, evidently originally designed as a servo unit but in actual practice riveted in place by gusset plates (shown at either end). Note that the T.E. of the tab is neatly flush-riveted, but the elevator itself has ordinary rivets.

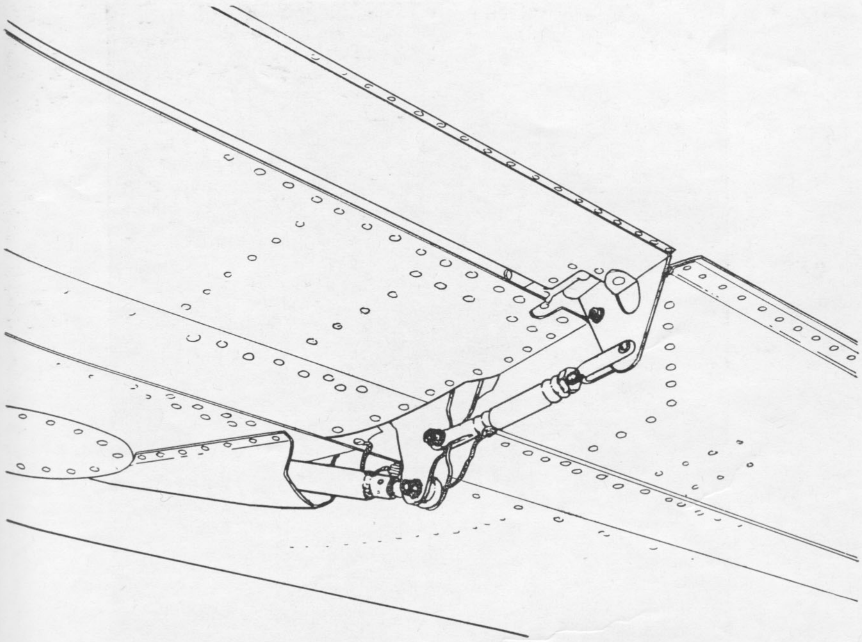


Fig. 7. The aileron trim tab apparently was originally designed as a servo unit, but in practice it turned out to be merely ground adjustable through a turnbuckle tie rod shown connecting it with the aileron control bracket. Note that the T.E. of the tab has flush rivets while that of aileron itself uses conventional rivets to hold the skin panels to the flat strip.

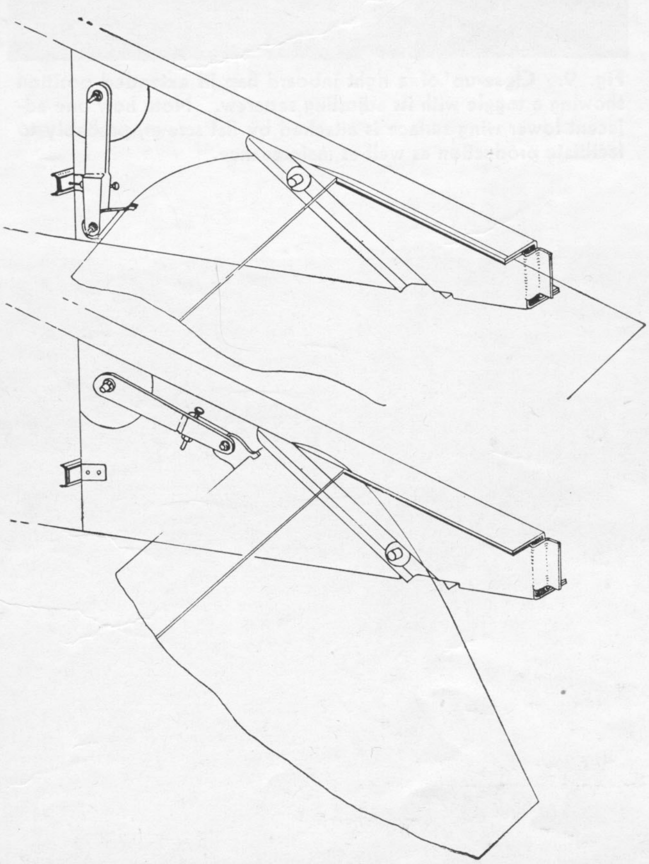


Fig. 8. Phantom sketch showing how flaps are moved back and down. A hydraulically operated toggle at the left forces the flap back, but a 7-in. track (which is channel-shaped) moves it down. A setscrew in the toggle arm can be adjusted for upstop.

These units, with .040 steel skin, extend from the fuselage line 40½ in. to the power plants, and from there to the wing tips, the outer segment being built in two sections 77½ and 48½ in. long, connected by a ½-in.-long steel pin.

Each segment is bolted to two curved steel guide tracks which slide over ball-bearing rollers bolted to wing ribs (2). Travel of the slots is a maximum of 6 in. at the inboard end and 2⅝ in. at the tip. Slots open automatically at 186 mph in the gliding angle and at 279 mph in a climb (3).

The 5¼-in. wing tip (4), with its integral formation light set in a transparent plastic covering, is built in two halves, flush-riveted to an inboard rib and spar. The two halves are welded together around the outer edge. The method of attachment is neat and can be accomplished fairly fast with simple tools.

Near the L.E., a horizontal pin slips into a holed angle plate on the wing-tip rib, then the tip is pushed toward the plane so that an angle bracket slips into a forged fitting riveted to the spar end, whereupon a through bolt with a self-locking nut is pushed down from the top through the small access holes (5). At the time the tip is pushed toward the wing, a vertical plate slips into a yoke attached to the end of the auxiliary spar with the result that a three-way fastening is obtained with only one bolt being necessary.

Of conventional design, the all-metal ailerons have a channel-section aluminum spar, rolled sheet-aluminum L.E., and stamped, flanged ribs. At the T.E. the two skin surfaces are crimped and riveted to a flat ¾-in. strip. Here, as on the rudder and stabilizer, the rivets are not flush.

Built in two sections, each aileron has a 42-in. span. The two sections are connected via a control bracket, which is split so that one half is riveted to the outboard rib of the inner section, the other to the inboard end of the outer section. A self-aligning ball-bearing hinge also serves as a connecting point for the two sections; similar bearings are bolted to ribs aft of the auxiliary spar at each end.

Evidently the 38⅝- by 3-in. trim tabs were originally proposed as servo tabs (6), but in practice they ended up as only ground-adjustable units, for the control arm, riveted to the outboard end of the inner aileron section, is attached by a turnbuckle rod to the aileron-operating bracket rather than

to the wing to give the servo action (7).

The flaps are in two sections, inboard, and movement is back and then down. A hydraulically operated toggle forces them back, but a channel-shaped track moves them down (8). A setscrew in the toggle arm can be adjusted for upstop (9). In a fully extended position, the flaps move down 50 deg. The upper wing surface extends back over slots so that in an extended position they are shrouded about $1\frac{1}{2}$ in. (10).

Wing attachment to the fuselage is by quite an unorthodox method. Near the base of the root nose rib, 9 in. aft of the L.E., a 1-in. bolt goes through a two-sided forged bathtub fitting which is bolted to the aft face of the bulkhead, backing up the front fuel cell. A similar-sized bolt is used on the root rib aft of the auxiliary spar. Then, riveted to the top wing skin at the fuselage line is a $1\frac{3}{16}$- by $1\frac{3}{16}$-in. steel angle member through which 17 bolts and self-locking nuts attach it directly to the fuselage skin.

On the first Me-262 brought to this country, many of the holes in the fuselage skin had been elongated and some were as much as $\frac{1}{16}$ in. out of line. When the plane was being prepared for flight tests, the holes were reamed to take $\frac{7}{8}$-in. bolts and an additional steel strip was used to back up the vertical half of the angle member.

The wing fillet, just over 73 in. long, is held in place by a cable anchored to an angle bracket at the T.E. and going under seven hooks riveted to the attaching angle member, with a turnbuckle at the front keeping it snug. The fillet around the L.E. is a drawn light aluminum-alloy section attached by eight flush screws.

Fig. 9. Close-up of a right inboard flap in extended position showing a toggle with its adjusting setscrew. Note how one adjacent lower wing surface is attached by flat screws, probably to facilitate production as well as maintenance.

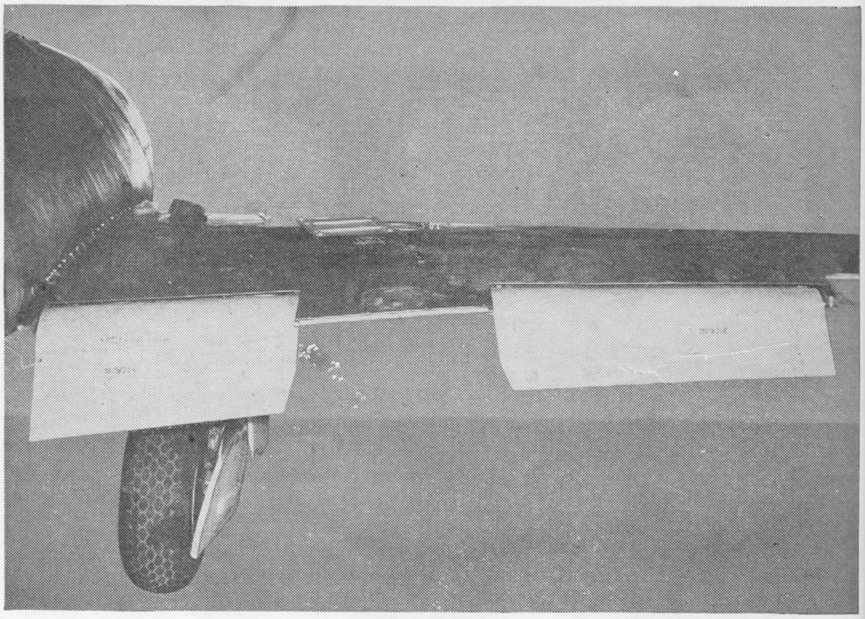


Fig. 10. Right-hand flaps in fully extended position, down 50 deg. The upper wing surface extends back over slots so that in an extended position they are shrouded about $1\frac{1}{2}$ in.

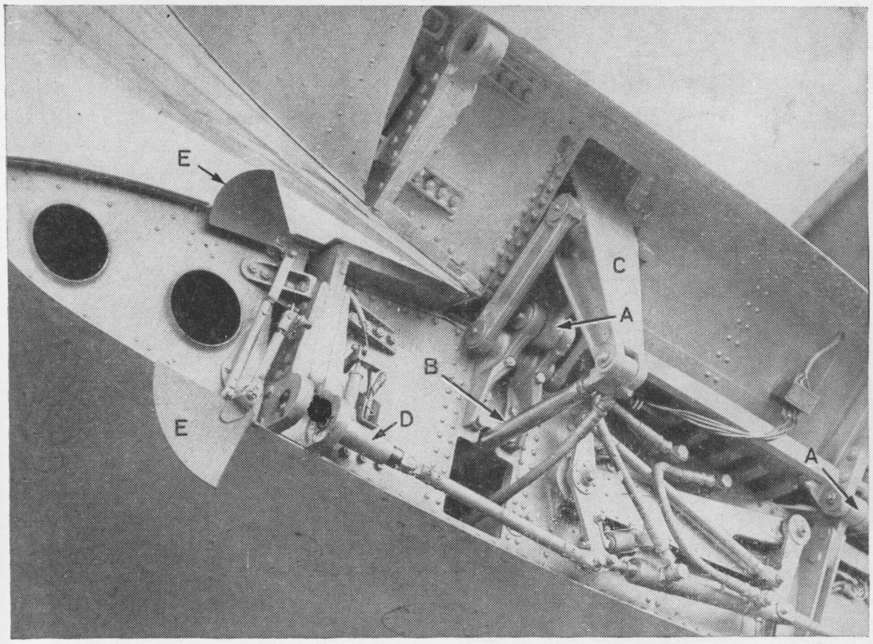


Fig. 1. Wing folding mechanism of the de Havilland Hornet, showing hinge points (*A*) of the outer panel which swings up and over the fuselage. Folding is accomplished hydraulically, with piston arm (*B*) actuating linkage (*C*). This piston has its hydraulic supply linked through sequence valves to locking pins (*D*). By a second lever, which the pilot cannot operate until the folding actuating lever has been moved, locking pins engage withdrawing pins, showing metal flags (*E*) unless the locking pins are secure.

De Havilland Hornet

A modification of the famous Mosquito, the Hornet is adapted and modified for naval carrier operations and is provided with a folding wing mechanism (1) to facilitate stowage. Hydraulic and electrical connections between the center section of the wing and the outer folding panel are made just behind the rear spar (2).

A metal structure is set in the wooden wing for reinforcement of the hydraulic jack which folds the wing panel up and over the fuselage (3). The main wing rib is of metal to which the hinges are attached (4). Reinforcement is provided by a hinge reinforcing box (5).

The outer panel is a combination metal and wooden structure (6). The single-web wood spar is turned over at right angles along the upper edge to pick up shear loads directly to the skin. This upper surface comprises an inner skin attached directly to the spars and ribs, with another plywood outer skin cemented atop the spanwise stringers.

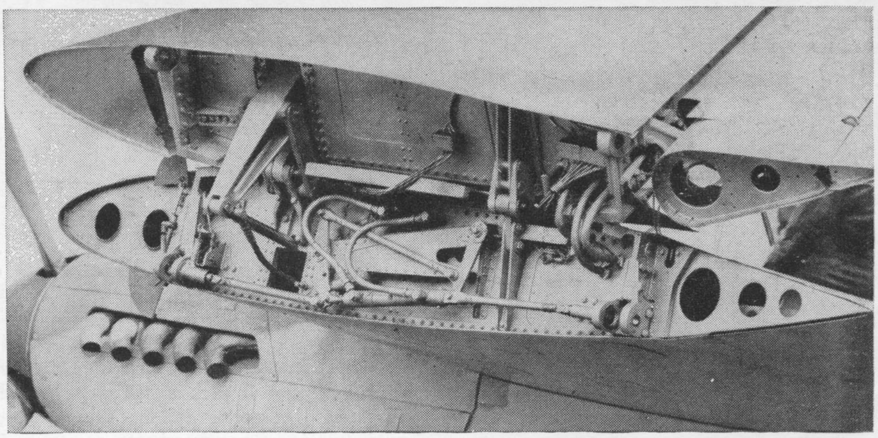


Fig. 2. View from the aft to the rear spar of a de Havilland Hornet, revealing complete wing-folding mechanism and showing, just behind the rear spar the method of making electric and hydraulic connections between the center section and the folding outer panel.

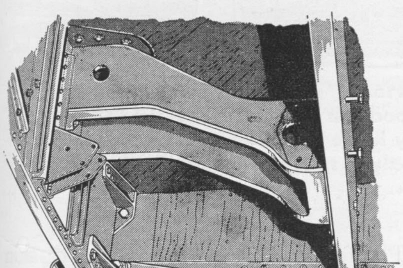


Fig. 3. View up into the wing of a de Havilland Hornet, revealing metal structure set in a wooden wing for reinforcement at the location of a hydraulic jack used to fold the outer wing panel up and over the fuselage.

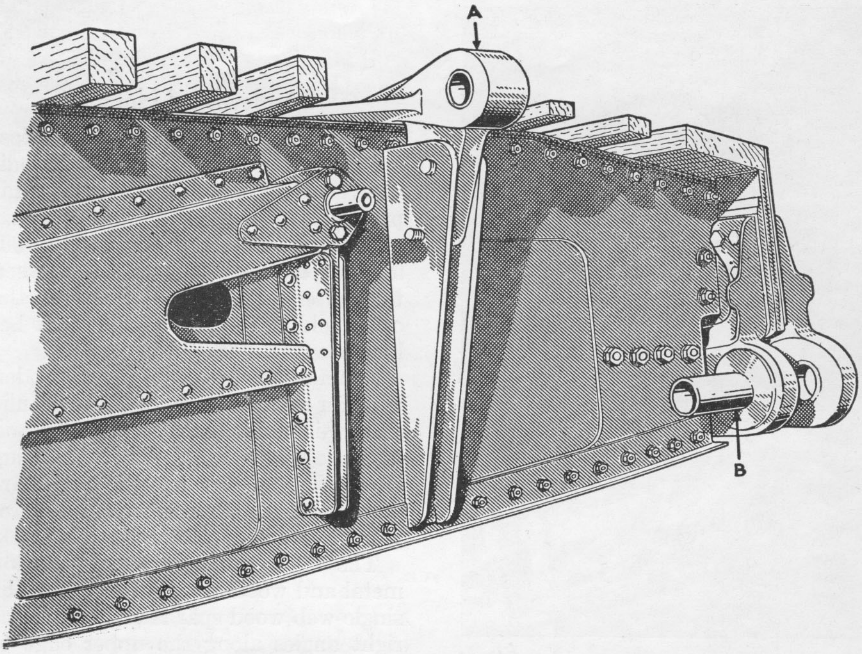


Fig. 4. Close-up of the wing main rib of a de Havilland Hornet, depicting the rear hinge (*A*) for folding the outer wing panel, and the locking pin (*B*).

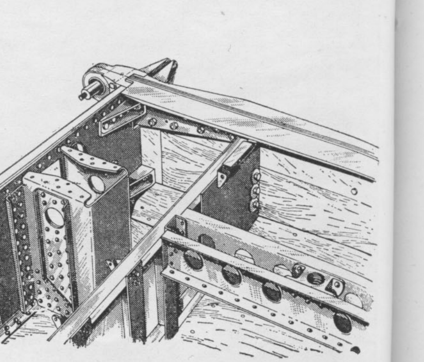


Fig. 5. De Havilland Hornet wing with the lower skin removed, showing the method of installing the hinge reinforcing box.

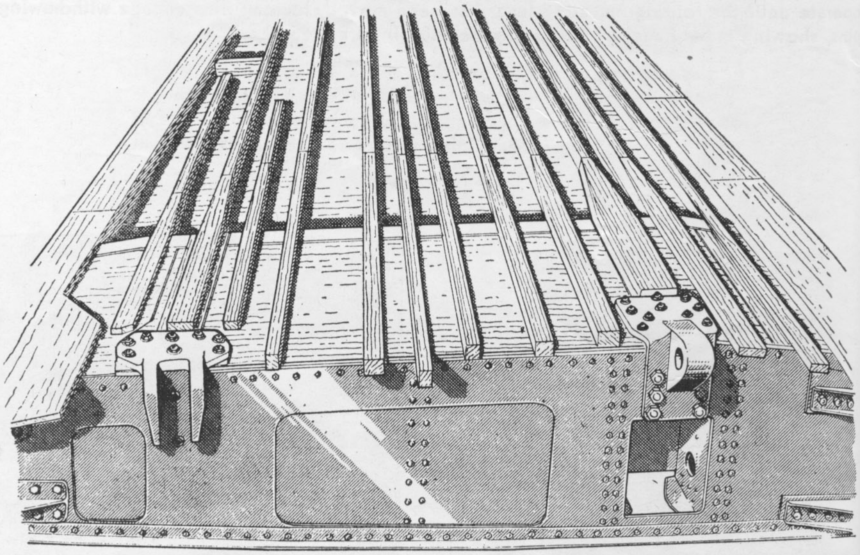


Fig. 6. A portion of the outer wing panel of a Hornet, showing the combination metal and wood construction. In this craft, a single-web wood spar is turned over at right angles along the upper edge to pick up the shear load directly to the upper skin. This upper surface, as shown here, comprises an inner skin attached directly to spars and ribs, with another plywood outer skin to be cemented atop spanwise stringers.

Grumman Mallard Amphibian

The prime consideration in the design of the planform of the Mallard's high wing was maximum single-engine climb, with maximum cruising speed, and stall characteristics secondary. The result was a wing area of 444 sq ft and an aspect ratio of 10 which is considerably higher than that of earlier models.

The taper ratio is 3, and the wing section 23021 at the root and 23012 at the tip. Although this root section was somewhat thicker than average, it introduced no adverse flow problems, eased structural considerations, and afforded additional fuel tank volume.

Planform, airfoil sections, and skin thickness are shown in (1).

The wing structure features a monocoque outer panel so that 68 per cent of the semispan has no vertical shear webs except for the flap beam. The center section uses a conventional box beam containing integral tanks sealed by the Stoner-Mudge process. Outboard of

the center section is the monocoque panel. The upper inboard surface has nine hat-section stringers, and this number is reduced to four at the tip. Five bottom-surface stringers reduce the outboard to three. The truss-type ribs vary in spacing up to 25 in.

The outer panel is riveted to the center section with only the skin for the transfer of loads. Stringers from the center section are noncontinuous with panel stringers being simply riveted side by side to the skin, the splice extending between two ribs approximately 14 in. apart. The same method is used farther outboard where the number of stringers is reduced. This, however, is not strictly a splice as it is inherently built while in the jig.

Although this system makes a very simple and smooth lightweight joint, it has the disadvantage of not providing bolt attachment of the outer panel. Field damage, therefore, requires riveting facilities and a crew for panel replacement, and alignment for field repair could be accomplished by the use of a carefully adjusted scaffold. The disadvantage of this arrangement is offset by the fact that it contributes to the low wing weight which is 72½ per cent less than that of the previous structures which were estimated.

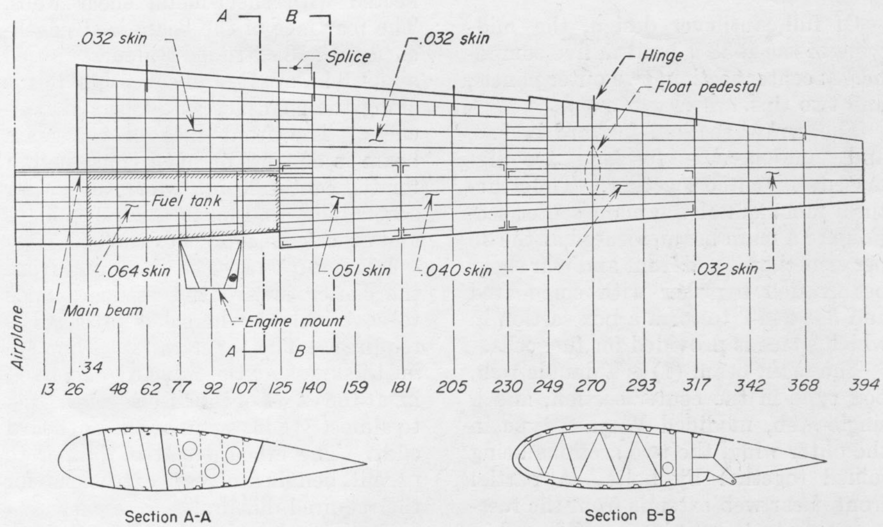


Fig. 1. Planform, airfoil sections, and sheet thicknesses for the wing of the Grumman Mallard.

The integral fuel tanks in the box beam of the center section directly aft of the engines require engine mount support attachments only at the flanges of the front and rear beams.

In general, closely spaced $\frac{3}{32}$ flush rivets are used in the structure except in the bottom. This unusually small size eliminated a large amount of dimpling with the substitution of countersinking. The result was an extremely smooth skin contour, especially in the light gauges. All sheets are 14ST or R301T, and extrusions are 75ST.

Martin B-26

The leading edge of the B-26 attaches to the main wing portion by means of piano hinges (1). This design not only facilitates production, but the removal of one hinge wire permits quick access to grouped plumbing and wiring leading out from the fuselage to the engine nacelles. Construction of the nose rib is shown at the right.

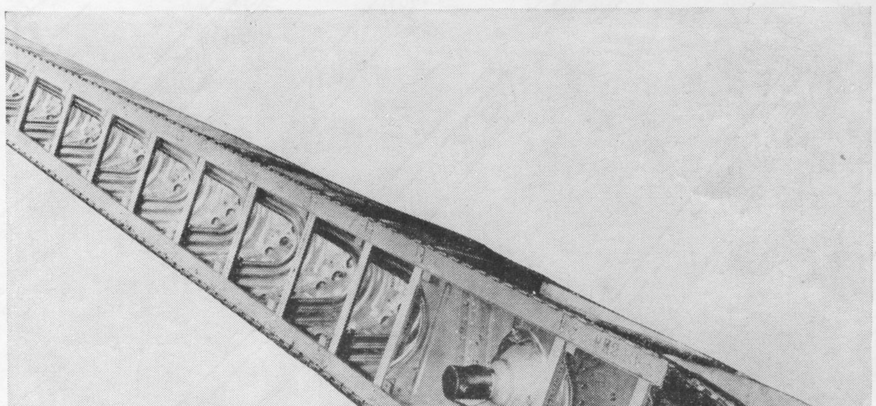


Fig. 1. Part of the L.E. of the Martin B-26 wing attaches to the main portion via piano hinges.

Lockheed P-38

Of full cantilever design, the mid-wing of the P-38 is built in five components: center section, two outer panels, and two tips.

The center section, forward booms, and gondola-type fuselage are jig-mated and bolted together. The structural members of the main center section are a main beam, located at the 35 per cent chord, and front and rear shear beams tied together with corrugated and flat 24ST to form a box section in which space is provided for fuel cells.

The main beam (1) is a double web, box type in the center section, and a single web, modified Wagner type in the outer wing, the two sections being joined together by bolts. A partial front shear web extends from the fuselage side to the engine nacelle, and in combination with the continuous full-span rear shear beam, completes the torsion structure of the wing.

Upper and lower center section main beam caps are 24ST extrusions connected with sheet-metal shear webs. The rear face of the beam is strengthened with 18 extruded stiffeners spaced about 6 in. apart, and seven bulkheads along the span act as additional stiffeners. The front face of the main beam is of truss or open construction for the center 30 in., which allows for accessibility and for location of pulleys and other connections to the cockpit.

Beam caps taper in thickness from the center toward the outboard ends to save weight where less strength is required. The taper ranges from $\frac{7}{16}$ in. thickness at the inboard end to $\frac{7}{8}$ in. at the edges of the fuselage and back to almost $\frac{7}{16}$ in. again at the outboard ends. The inboard end is thinner to permit bending of cap extrusions for the required dihedral.

The main beam varies in depth from 19 in. at station 0 at its inboard end, which is the plane's center line, to $13\frac{1}{2}$ in. at the point of attachment of the outer panel.

The box beam is composed of main beam, rear shear beam, and upper and lower surface—flat and corrugated—structures. The skin is stiffened by spanwise corrugations which help carry bending and air loads of the wing. Main beam webs are $5\frac{1}{4}$ in. apart and .040ST alclad aluminum. Corrugations in the center wing section are .064SRT and .032SRT alclad. The upper and lower skin is .040ST aluminum. The lower skin is strengthened with an .040 doubler extending inboard from the outboard end to a diagonal line about halfway to the center line.

A single web, modified Wagner-type rear shear beam is built of extruded T's and sheet stock.

Wing fittings of 14ST forgings attach to upper and lower main beam caps and are formed multifingered, pin-joined (2). For connection of the outer wing main beam, the fittings on the outer wing are multifingered steel forgings, to reduce their size and increase the faces carrying the shear loads.

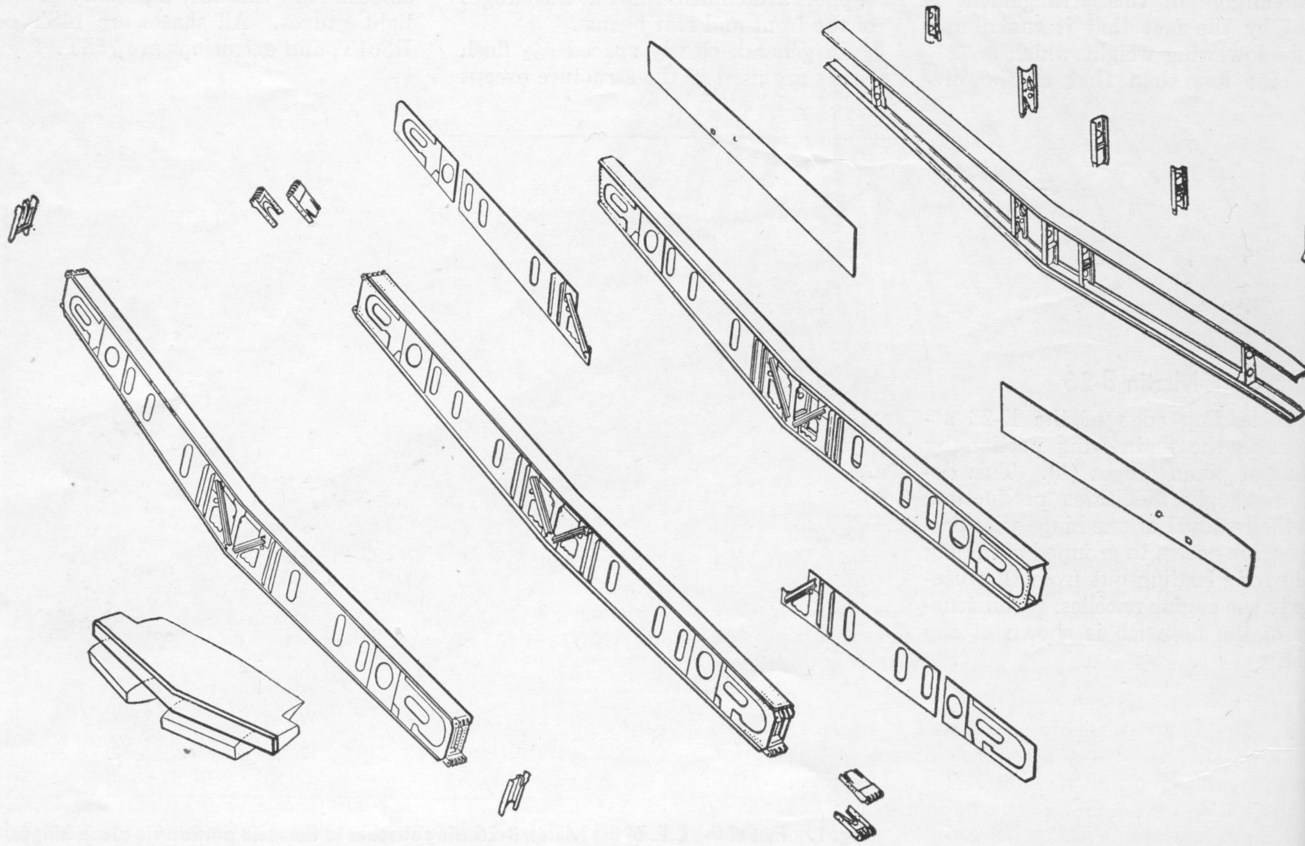


Fig. 1. Exploded view of the main beam in the center section, showing double-web, box-type construction. Note the variety of bulkheads, and upper and lower channels (right), aft, front inboard, and front outboard web assemblies (center right), upper and lower wing fittings (center left), and completed center section beam with end bulkheads (left). The position of the main beam in the center section is shown at the extreme left.

Rear shear beam of the outer wing joint is a simple shear fitting, steel pin connection at upper and lower caps. Corrugations of the surface structure are spliced at the outer wing joint by aluminum alloy forgings and tension bolts.

The box structure and leading-edge section forward of the main beam extend from the fuselage to the engine nacelles and form a two-cell torsion box which carries torsional loads to the fuselage. Surface structure through the center section (3) is stabilized for a portion of its length from the center line outboard to the fuselage edge with ribs built up with sheet-metal stampings. From that line to approximately where the booms attach to provide space for fuel tanks in the box beams and L.E. sections, the surface structure is unsupported.

The L.E. sections have chordwise formers in both upper and lower surfaces instead of ribs extending from the main beam to the front shear beam. The front beam is interrupted at the fuselage and nacelles, and the loads are taken across by the box beam between the main and rear spars.

Flush rivets attach the .025ST inner

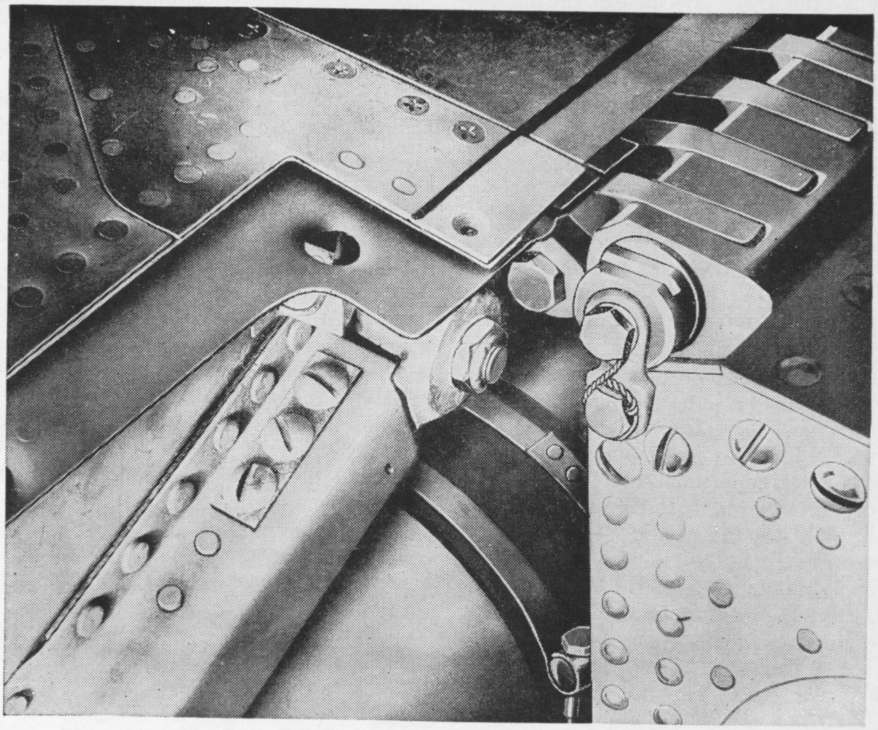


Fig. 2. Main beam fitting at the wing. The fittings are multifingered, pin-joined, and of 14ST or steel forgings depending on the place of use.

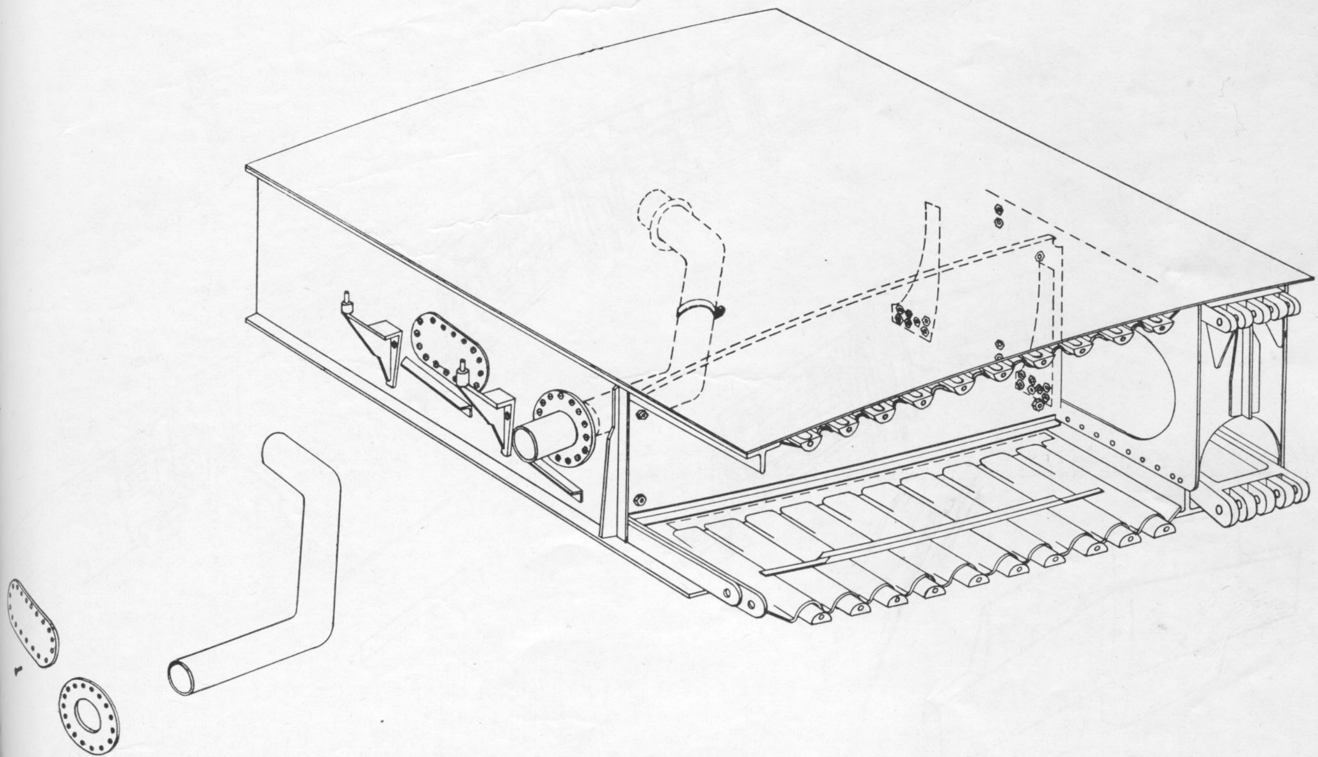


Fig. 3. View of the center section illustrating how the skin is stiffened by spanwise corrugations which also help carry the bending and air loads on the wing.

skin to the corrugated stiffeners in the gas-tank area. Because of the inaccessibility, it was necessary for Lockheed tooling engineers to develop a magnetic bucking bar for this operation, which was typical of the many manufacturing problems posed by the pioneering done on the P-38.

The center section trailing edge (4) consists of sheet-metal ribs and intercostal stiffeners which support the upper skin, and Lockheed's design of Fowler flaps (5). These consist of a main spar formed with a sheet-metal web and formed sheet-metal caps, sheet-metal ribs and stringers. They are carried on forged 14ST arms guided on tracks machined from 14ST forgings. They extend from either side of the fuselage outboard to the inner end of the aileron, a distance of approximately 180 in., with the exception of a section about 43 in. wide, omitted at each boom.

The flaps are secured to the wing by eight carriages supported in tracks attached to the flap-supporting ribs and providing for extension aft in line with the flight path so that, in extended position, the flap L.E. corresponds approximately to the wing T.E.

Outer wing panels (6) consist of main beam, rear shear beam, and upper and lower stressed skin, forming a box beam, and hydropressed sheet 24ST ribs spaced at 12-in. intervals. The outer skin and corrugated stiffener are 24ST alclad.

The L.E. (7) has no ribs and is made up of formed inner skin and shallow chordwise corrugations of 24ST. These are built up of upper and lower halves, joined at the L.E. with piano-hinge fittings, and are removable. In earlier models, the intercoolers were housed in the wing L.E., which now carries the fuel cells.

A flush-type L.E. running light is incorporated in the port side. The skin, of .040-gauge 24ST alclad, is flush-riveted and butt-jointed.

The outer wing panel main beam consists of upper and lower beam caps which are 24ST aluminum alloy extrusions, tapering out from the center until a heavier reinforcing section disappears and the extrusion becomes a plain angle of sheet metal. The lower cap tapers faster than the upper and is finally replaced by a pair of sheet-metal angles.

Dive flaps were added to offset a compressibility effect which shifted the center of lift from fore to aft portions of the wing (8). Because of the unusually high speeds attained by the heavy P-38 in power dives, the shifting of the center of lift caused a loss of normal control above the "hydrodynamic" speeds—where air reacts much like water—with a resulting tendency of the plane to go into an outside loop. Since installation of the flaps, this characteristic has been overcome.

Fabricated of three layers of aluminum alloy sheet, the flush-riveted flaps are attached by a piano-type hinge along the same line at which the L.E.

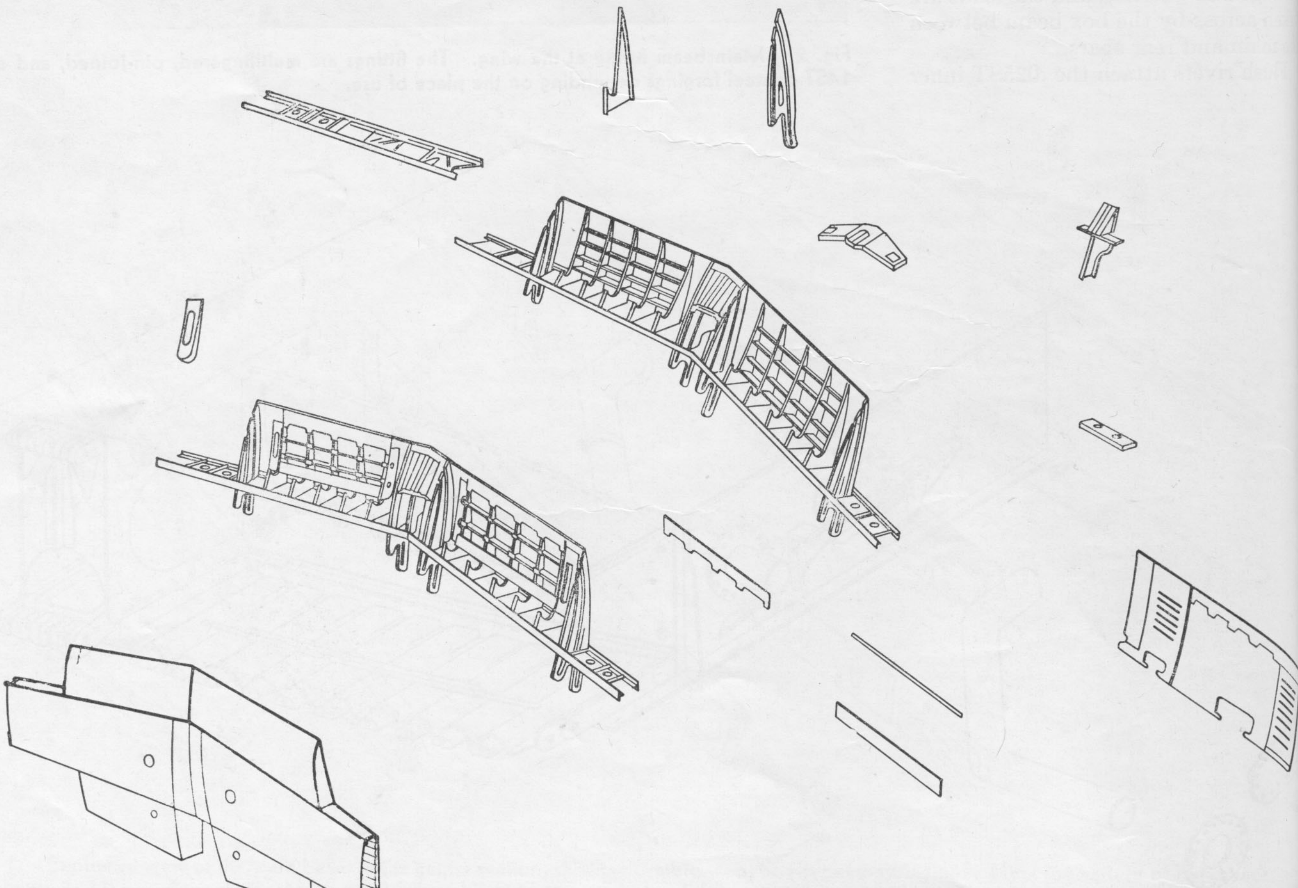


Fig. 4. Exploded view of the T.E. of the center section, showing sheet-metal ribs and intercostal stiffeners, which support the upper skin, and Lockheed-Fowler flaps, which form the lower skin when closed.

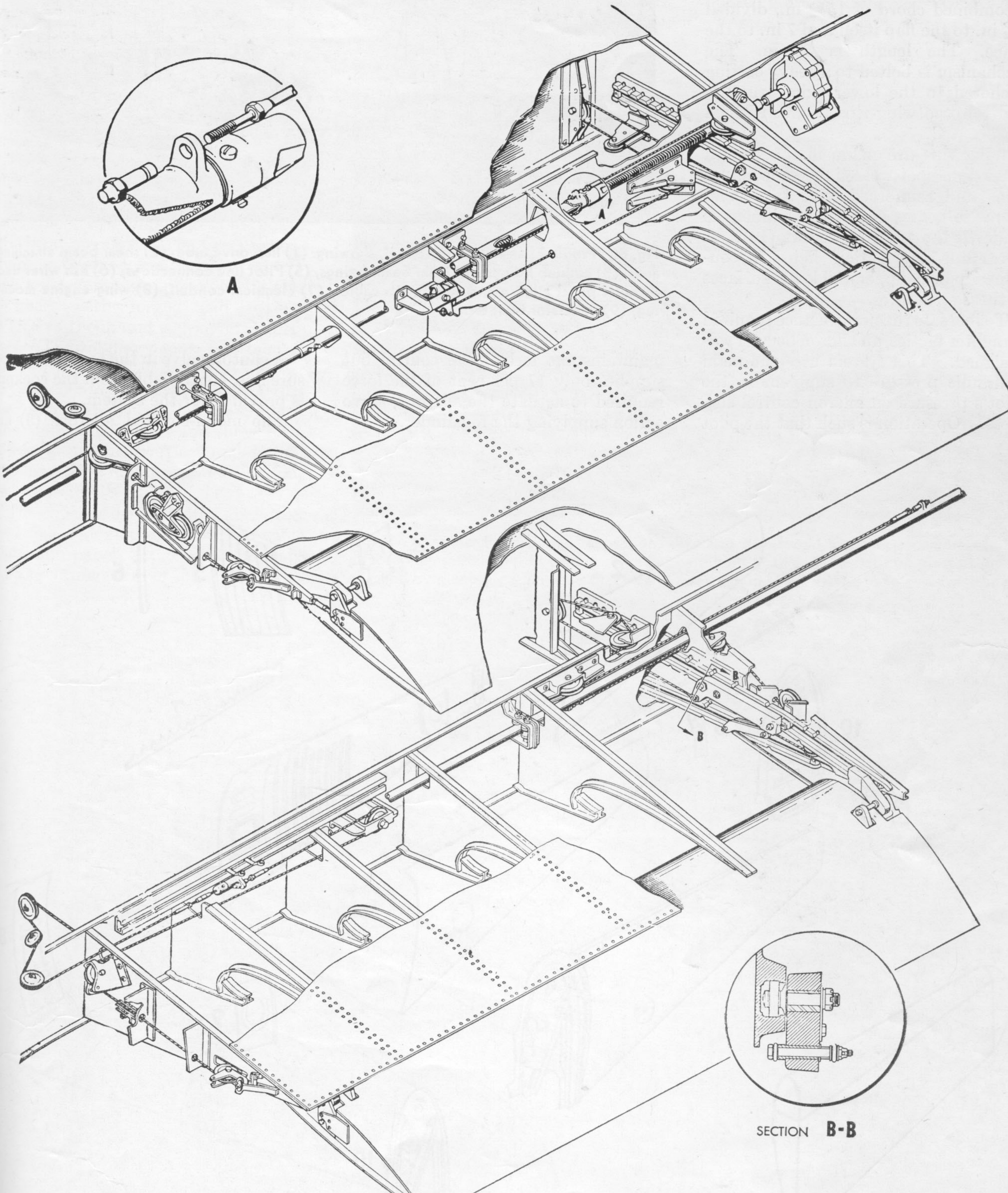


Fig. 5. Cutaway sketches showing details of the center section flap (top) and the wing flap (bottom). Hydraulic actuation is by means of push-pull tubes and ⅛-in. preformed tinned carbon-steel cables. Lockheed-Fowler-type flaps are used for take-off, maneuvering, approach, and landing.

of the wing is joined to the outer wing panel. The flap and brace panels have a combined chord of 15½ in., divided 8½ in. to the flap itself and 7 in. to the brace. The length is 58 in. The mechanism is bolted to a heavy casting anchored to the lower skin structure and the two wing ribs between which it is located.

Wing tips are made up of smooth outer skins spot-welded to beaded inner skins and reinforced with two small spanwise beams each. Attachment is made to the wing by screws (10). A streamlined formation light is contained in both upper and lower surfaces of these structures.

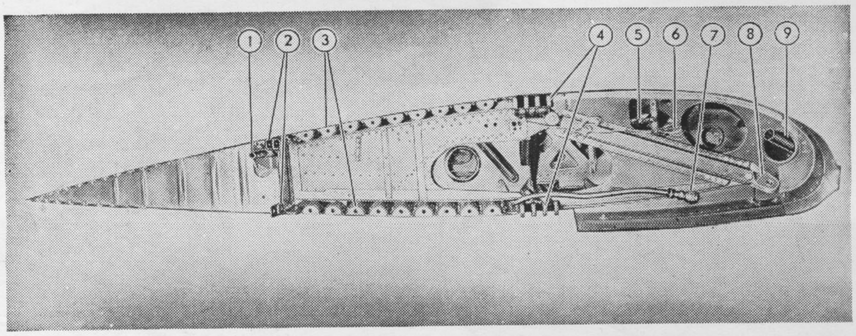


Fig. 6. Profile of an outer wing panel, showing: (1) flap drive tube; (2) shear beam attaching arms; (3) bathtub fittings; (4) main beam fittings; (5) Pitot line connections; (6) fish wires tied to outer panel aileron and aileron tab cables; (7) electrical conduit; (8) wing engine mount lug; (9) generator blast tube.

To increase the performance required by fighter tactics, an aileron booster was designed. This system uses the main hydraulic pressure to supplement the pilot's pressure on aileron control surfaces. Operation is such that the pilot maintains the feel of the control but supplies only 17 per cent of the force required to actuate the ailerons, servo action supplying the remainder.

A shutoff valve in the hydraulic pressure line, controllable from the cockpit, is provided for the system.

The metal-covered ailerons (9) are

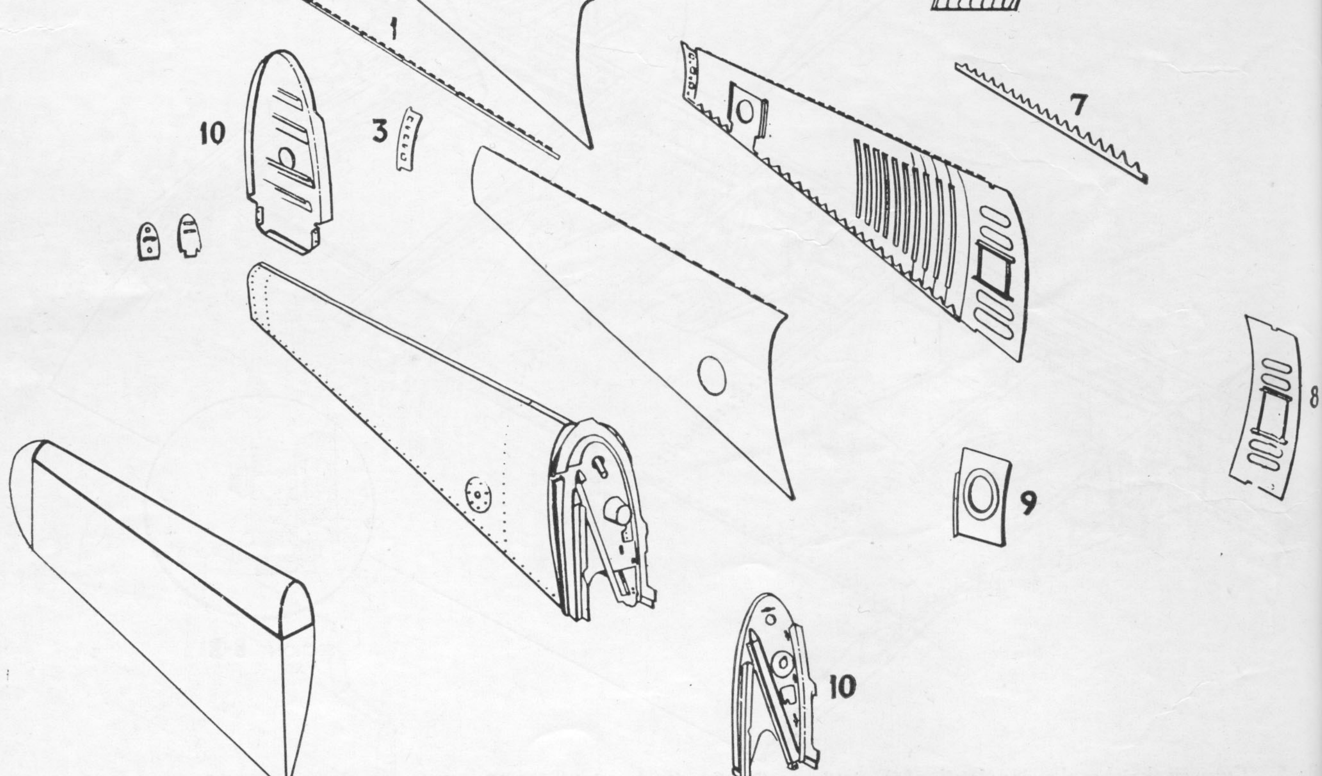


Fig. 7. Leading-edge assembly, outer wing, showing: (1) well; (2) skin; (3) doubler; (4) filler plate; (5) corrugations; (6) capstrip; (7) finger piano-type hinge; (8) doubler; (9) sump well; (10) ribs.

of standard design and have a total area of 24.44 sq ft, an angular movement of 25 deg up and 20 deg down, a differential movement of 2.3 to 1, and the distance from the plane of symmetry to the centroid of the aileron area is 230.4 in. They are statically and dynamically balanced and are attached to the wing by stainless-steel piano-type hinges.

The engine nacelles extend forward from main beam of the wing and join the booms at the fire wall, the latter being merely a bulkhead and not a structural member. The nacelles consist of an engine mount with two 14ST side truss forgings and steel tubular members with forged end fittings welded to them, and support bay forgings. The tubular members attach to ribs in the wing L.E., and the support bay attaches to the forward boom structure, giving the mount lateral support. The combined forgings and tubes form a truss providing vertical and lateral support. The mount attaches by four nickel-steel bolts.

The cowling consists of 9 mild steel lower nacelle and quickly removable aluminum panels attached to the supporting framework of pressed aluminum alloy and steel attached to engine itself and mount by flush-type fasteners. Bottom cowling skin and sections around the exhaust manifolds are steel. Intercoolers are below the engines and housed within the engine cowling.

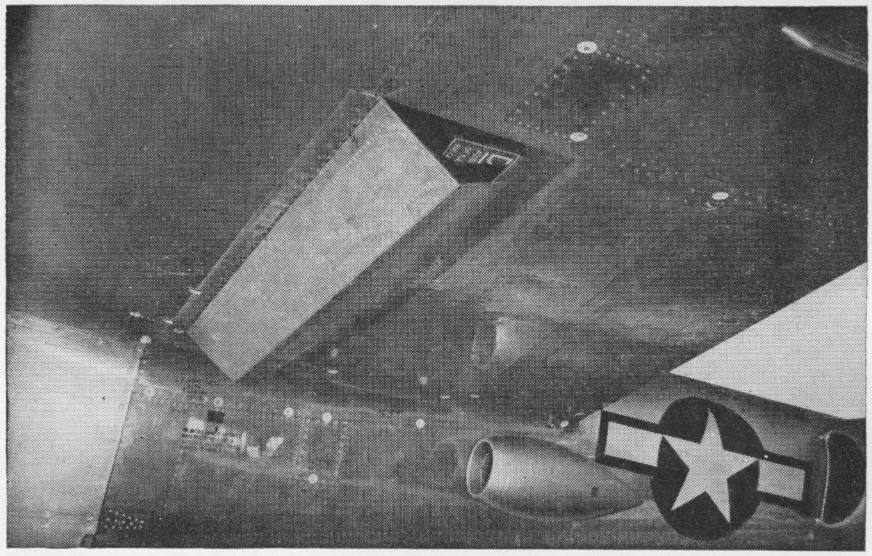


Fig. 8. Another P-38 design innovation; dive flap developed to offset a compressibility effect which shifted the lift center. The flaps are built of three layers of flush-riveted sheet, attached by piano-type hinges. Electrically operated, the flaps extend to an angle of 40 deg.

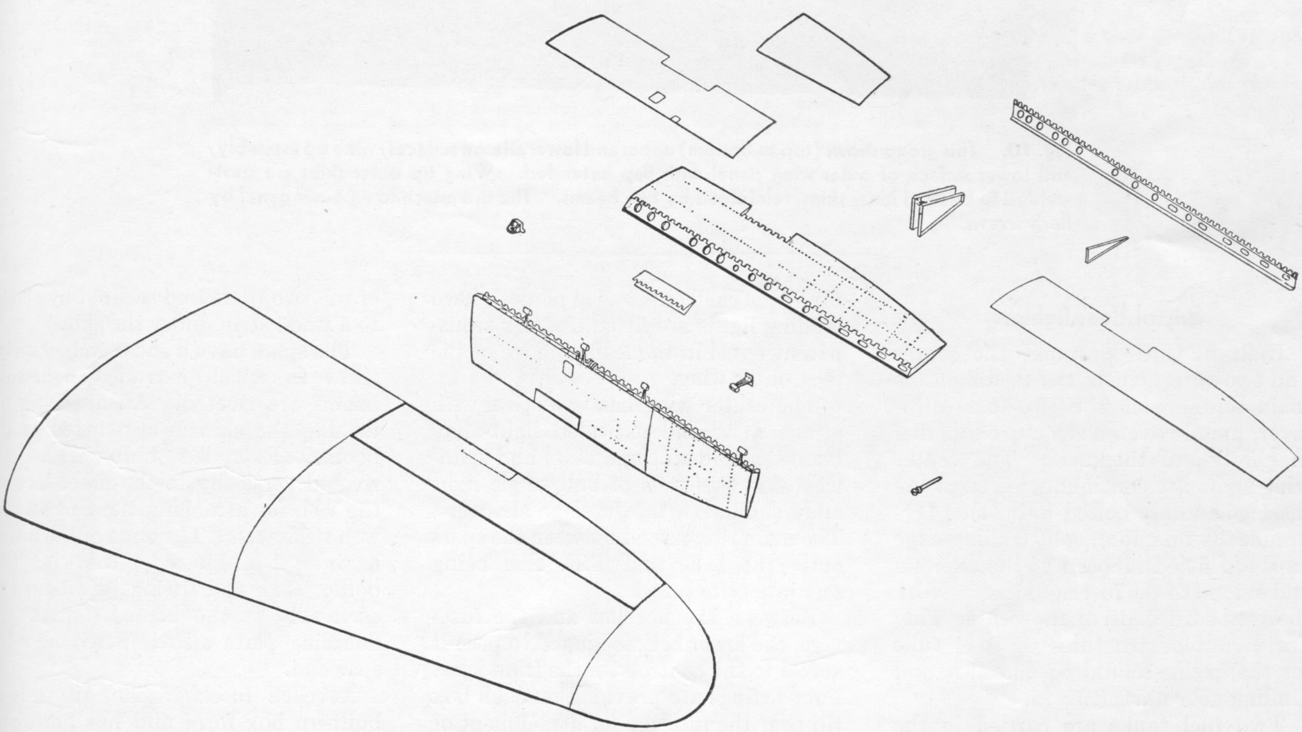


Fig. 9. Exploded view of aileron components, showing a front beam (extreme right), around which the unit is built, typical ribs, upper and lower flush-riveted skin panels, and control counterweight details. Piano-type hinges are employed for attachment to the wing.

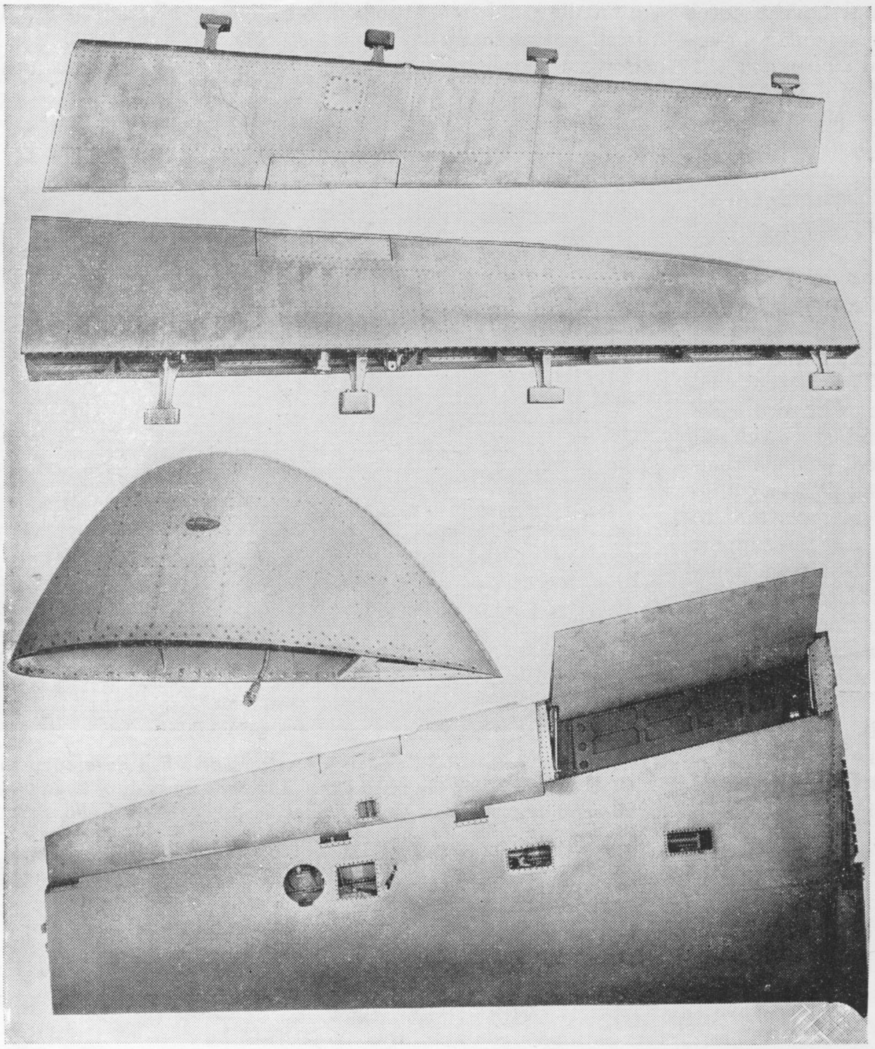


Fig. 10. This group shows (top to bottom) upper and lower aileron surfaces; wing tip assembly; and lower surface of outer wing panel with flap extended. Wing tip outer skins are spot-welded to beaded inner skins, reinforced by two beams. The tips attach to an outer panel by flush screws.

Bristol Beaufighter

Built in three portions, the center and two outer panels, the Beaufighter's main center wing is a two-spar cantilever, metal-covered structure tapering in chord and thickness. The center wing spars are continuous through the fuselage and are bolted to it (1). Hydraulically operated, split trailing-edge flaps are fitted inboard of the ailerons and extend to the fuselage sides. Near the outboard ends of the center wing are mounted structures of steel tube for the engine mounting, nacelles, and landing gear units (2).

Two fuel tanks are carried in the center section, one on each side of the center line (3), and single tanks are carried in each outer wing plane. Two landing lights are fitted under a transparent panel in the leading edge of the port outer wing.

The center wing has two spars with alclad webs and extruded light-alloy booms, alclad ribs and skin, and spanwise skin stiffeners of bulb-angle light alloy similar to the fuselage stringers. The main ribs extend between the spars only, the L.E. and T.E. ribs being separate structures.

Between the nacelles and the fuselage, the lower L.E. is hinged to permit access to the controls on the front spar. Four fittings are provided on each box rib near the fuselage for attachment of the center wing to the fuselage, and fairing fillets are fitted at the juncture of the two parts and secured by screws to a wood strip under the skin.

The spars have a shear web of alclad sheet to which extruded light-alloy booms are riveted. An angle for attaching the skin is also fitted at the booms. Extruded bulb angles are riveted vertically to the inner faces of the web for attaching the ribs and for web stiffeners. The ends of the booms have steel bushings for the wing-joint bolts. The end fittings are bolted to each side of the booms, and a web doubling plate also is fitted near the spar end.

At each fuselage side, rib 1 is of built-up box form and has horizontal forked blocks of light alloy riveted to the bottom corners, and vertical forked

blocks bolted to it at the top corners. These blocks have pressed-steel bushings for the center wing to fuselage attachment bolts.

Landing gear attachment ribs have an alclad web with top and bottom flanges of alclad lipped angle and are reinforced by a bracing of square light-alloy tubes and vertical bulb angles.

The end ribs each consist of an alclad plate web with flanged lightening holes and vertical light-alloy stiffeners of bulb angle, and top and bottom flanges of alclad channel riveted on one side. The remaining interspar ribs, which are without web plating or bracing, consist of top and bottom booms. The top booms consist of channel and I sections riveted to the skin; the bottom ones form bearers for the tanks and are I section.

The L.E. of the plate ribs is stiffened diagonally by bulb angle and supported by similar struts. The upper skin is riveted, while the lower forms a hinged door. Ribs are bolted to the spar booms, and skin is riveted to the angle bracket on the front spar.

In two portions, the T.E. is built of alclad ribs and skin. Ribs are bolted to the spar booms, and skin is riveted to the angle bracket on the rear spar. The after portion, opening on the bottom for flaps, is secured to a false spar by setscrews and bolts with Simmonds nuts at the aft end of the forward portion. There also is a bulb-angle stringer, top and bottom, at about mid-chord.

The outer wings (4) generally are of similar construction to the center section and are attached to it at the spars. The spar and T.E. construction resembles that of the center wing. A sealing strip between the center and outer wings is secured by setscrews. Top booms of the outer wing spars have

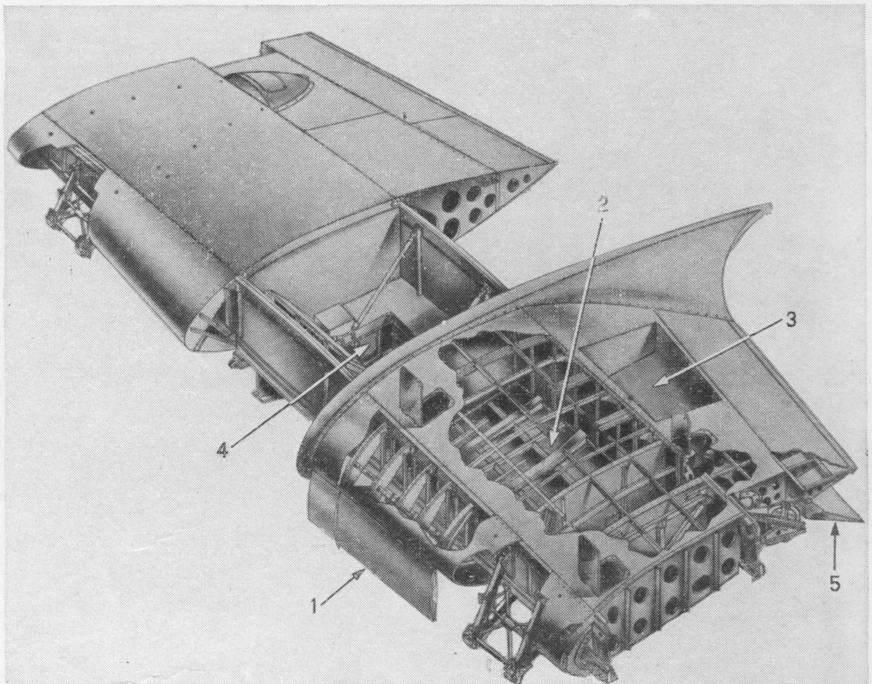


Fig. 1. The center wing section is equipped with a hinged L.E. (1) for access to controls, wiring, etc. The inner fuel tank rests on curved bearers (2) between the front and rear spars. The square cavity in the left wing behind the rear spar contains a rubber dinghy (3). At bottom center (4) is the pilot's entrance and emergency exit for parachute jump. Flaps (5) are hydraulically operated, the two sides being synchronized by the cable shown running over a pulley.

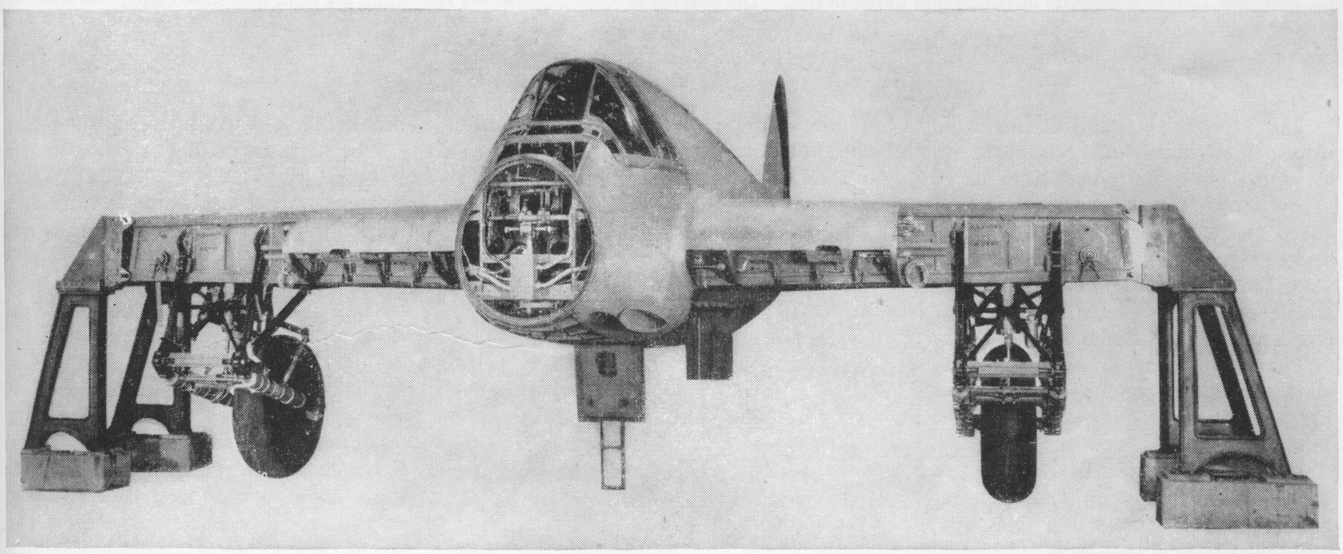


Fig. 2. Fuselage and wing center section complete with landing gear. Blast tubes for cannon are at the lower sides of the fuselage. The pilot's exit trap with ladder extension is shown open. A bulletproof glass window is in place with bad-weather openings at the sides.

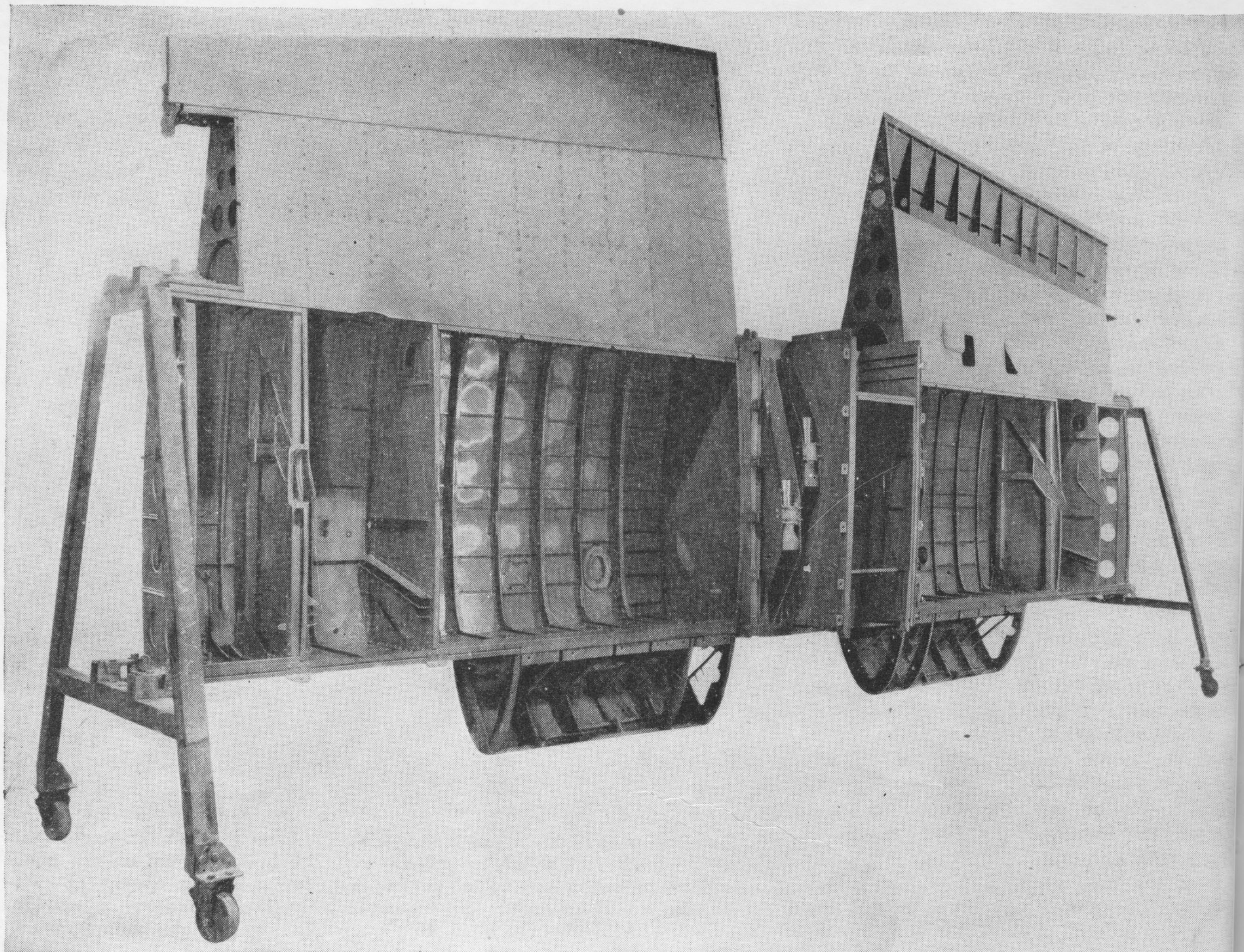


Fig. 3. The wing center section from below. At the center is the entrance trap with cannon mountings on each side. Outside this location is the fuel-tank compartment with filler opening between ribs. The flap is shown in place at the left, while the right side shows wing ribs with flap removed.

forked, steel-bushed end fittings which interlock with, and are bolted directly to, center wing spar end fittings.

Similar bottom-boom fittings are secured to the center wing spars by bolts and link plates on each side. In addition, the webs of the center and outer wing spars are connected by bolted channels and tie plates.

The main interspar ribs have an alclad web plate stiffened by vertical light-alloy angles and flanges of alclad bulb angle. The remaining ribs have top and bottom booms of alclad channel interconnected by light-alloy angle. At the fuel tank position, the upper and lower booms are similar to those of the center wing.

The L.E. ribs have two overlapped plates stiffened diagonally by flanges and bulb angle with front portions completed by fitting a wooden block. The skin of both the upper and the lower surfaces is riveted to the ribs, which are bolted to the spar booms, while the skin overlaps the angle bracket on the front spar and is riveted to it.

Of flanged plate construction, the outer wing tips are supported by plate ribs with intermediate ribs of light-alloy bulb angle and riveted alclad skin. They are secured by screws to the outermost wing rib and are detachable. The outer end is transparent sheet enclosing the navigation and formation running iight, which are mounted on the outer end rib. A later modification introduced plastic lights mounted in tubular brackets to replace the formation lights.

The flaps are built in four sections—left and right center and outer wing flaps—and extend from the fuselage sides out to the ailerons. They are operated by two hydraulic jacks, the left and right ones being interconnected by balance cables for simultaneous action. The flaps mainly are of alclad and have channel ribs, a Z-section spar at the forward face, channel transverse stiffeners near the mid-chord, and a rectangular tube T.E.

Brazier-head rivets secure most of the bottom skin to the ribs, stiffeners, and spars. Chobert rivets are used on the top and on the last three rows on the bottom. The lower skin projects beyond the T.E. and, when the flaps are

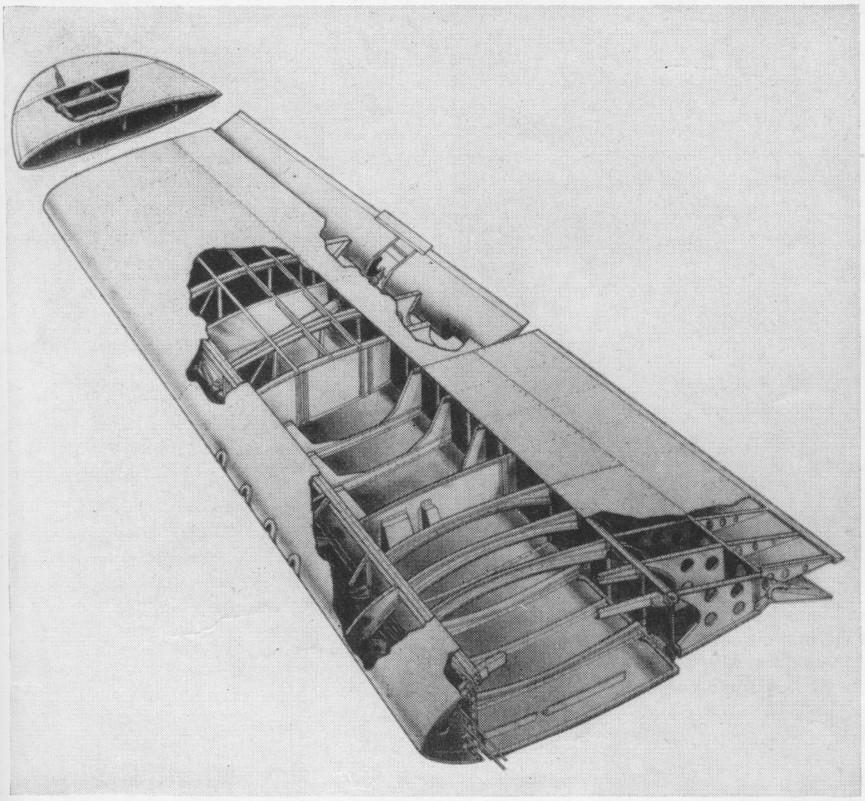


Fig. 4. The outer wing consists of two main spars with a false spar in front of the flap. At the inboard end is space for the fuel tank, outside which are four machine guns and ammunition boxes. Beyond these is the aileron-operating mechanism. The aileron is fabric-covered on an alloy frame. Hydraulically actuated flaps are at the inboard end of the wing.

raised, closes the rear gap beneath the wing. Piano hinges on the bottom of the flap spar connect the flaps to the false spar of the wing. A dural horn is bolted to the outboard end of each center flap and to the inboard end of each outer flap.

To give a quick change from high to slow speed for dropping torpedoes, torpedo-carrying Beaufighters were fitted with special bellows airbrakes (5). Immediately outboard of each engine is a venturi tube with a butterfly throttle at the rear end. This tube is connected to the airbrakes, and when the throttle is open, the partial vacuum in the venturi sucks the brakes flat against the wing surfaces. When the throttle is closed, air pressure builds up and fills the bellows, extending the brakes (6).

Ailerons have dual tube spars, with ribs, nosing, and T.E. of alclad sheet and fabric skin. Two mass-balance weights are fitted in the nose of each aileron, and the hinge points are inset to obtain aerodynamic balance (7).

The spar is of dural tube on which flanged alclad plate ribs are secured by collars and taper pins. Eyelets for attaching the fabric are in the rib flanges. The alclad sheet nosing is bent round and riveted to the rib noses, and the lead mass-balance weights are riveted inside along its entire length.

Outboard and inboard of the trimming tab, the T.E. of alclad sheet is riveted to the ribs. A dural tube, from the rear outboard corner to an eyebolt through the spar, reinforces the outboard end of the aileron. Three ball-bearing hinges on each aileron are attached to special tail ribs on the outer wing.

The trimming tab on the left aileron is made of light-gauge stainless-steel sheet secured by countersunk screws on the top and by roundhead screws in elongated holes on the underside, thus permitting a small amount of adjustment for lateral trimming to be made on the ground. The fabric of the aileron passes around the former to which the tab is secured but does not pass over the tab.

The right aileron trimming tab, operated from the cockpit, is of alclad sheet bent to shape and hinged to the trimming tab former. A horn is fitted to underside of the tab.

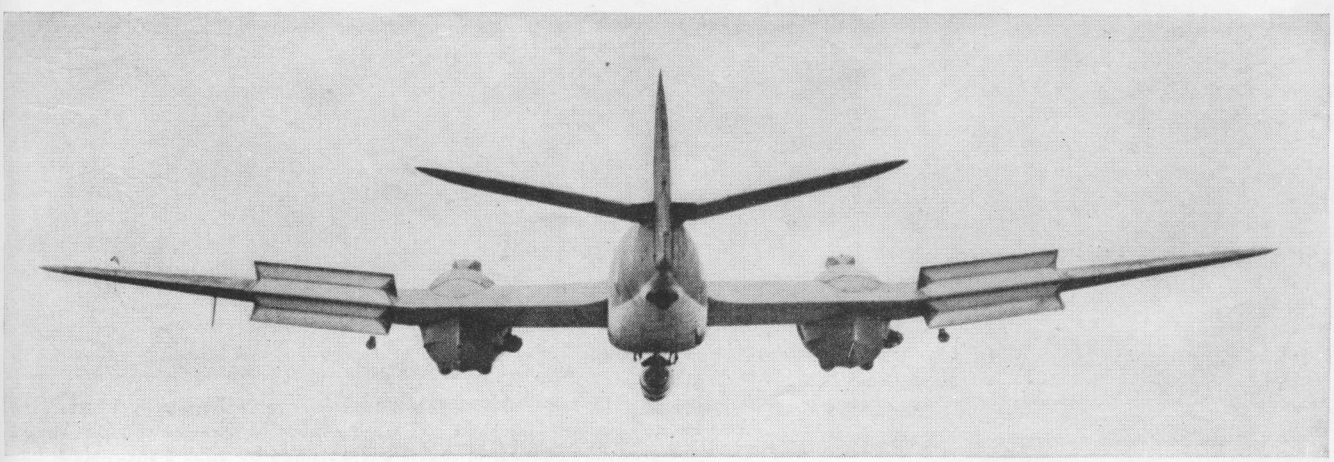


Fig. 5. Rear view of the Beaufighter, with dive brakes open ready to drop a torpedo.

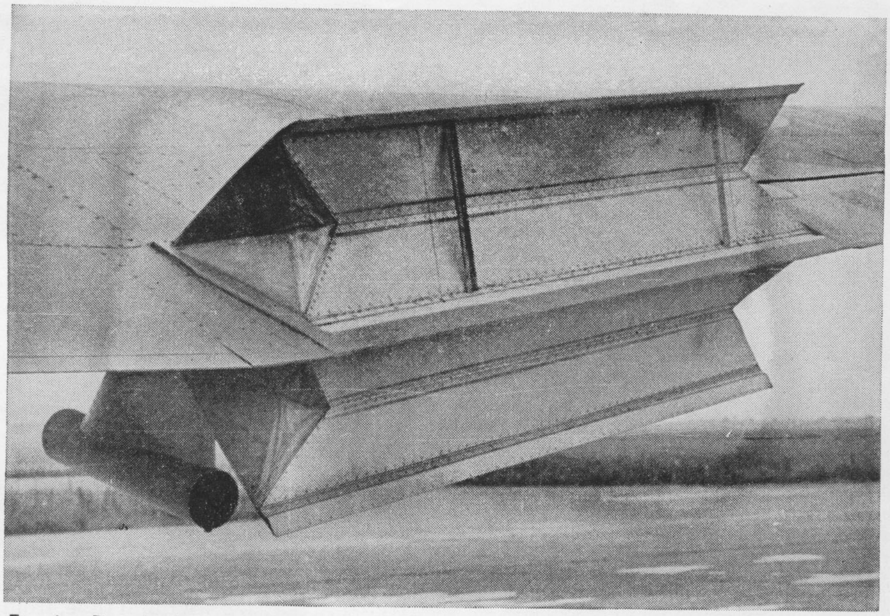


Fig. 6. Dive brakes are operated by a venturi tube beneath the wing. When the damper at the back of the tube is closed, air pressure opens the brake bellows. When the damper is opened, venturi suction draws the bellows together to conform with the wing surface. Braces are inserted in the top bellows to hold them open for photographic purposes.

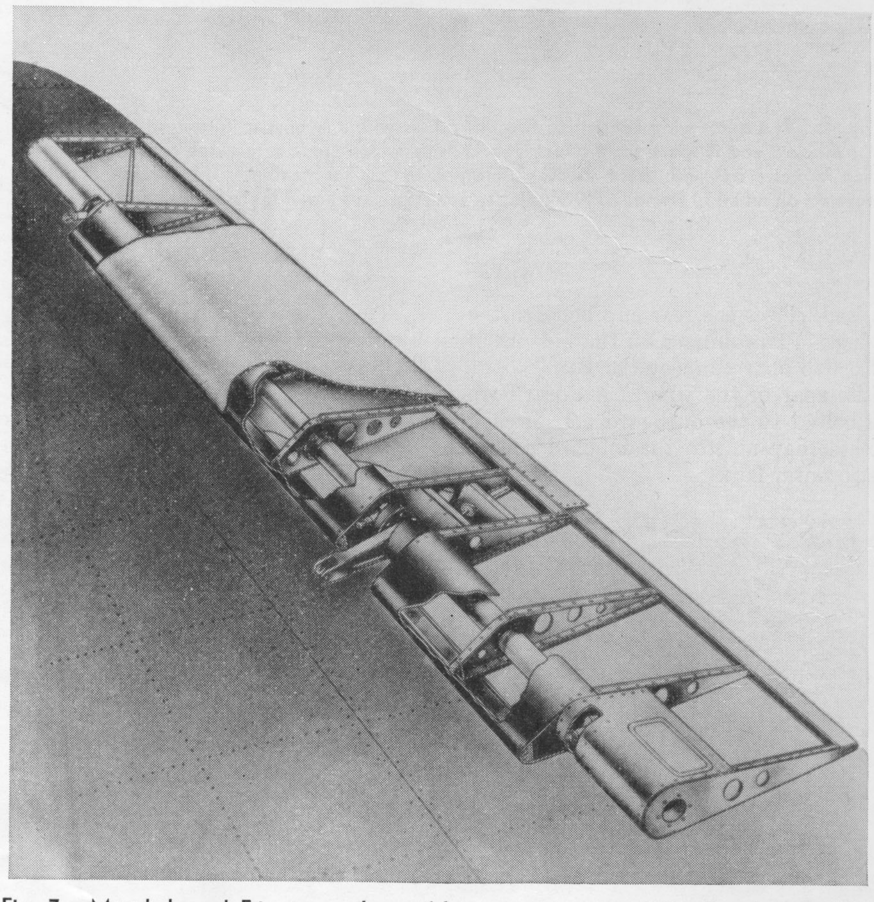


Fig. 7. Mass-balanced Frise-type aileron, fabric-covered over a light-alloy frame. The aileron is hinged at three points. The right trim tab is controlled from the cockpit, but the left one is set on the ground. Stiffness of structure is obtained by using a sheet-metal L.E. and a tubular strut at the outer end.

Douglas A-20

The full cantilever aluminum alloy wing of the A-20 has a single spar and two shear webs. It is the NACA 23018 section tapered to NACA 23010 at the tip, selected because of its very stable center of pressure.

Built in six major sections, the wing consists of left and right inner panels, extending from the fuselage junction to approximately 60 in. beyond the center line of the nacelles; left and right outboard panels, similar in construction to the inner ones and extending to about 30 in. inboard from the tip; and the left and right wing-tip assemblies which complete the wing.

The inboard wing panels (1) are connected to the fuselage structure by aluminum alloy fittings and close-fitting steel bolts in shear. The outboard and inboard panels are joined by tension bolts at the center spar, and by shear bolts at the forward and aft shear webs. The wing tips are attached to the outboard panels by means of flush screws and anchor nuts.

The single Wagner spar (2) carries all bending loads. Wagner-type ribs and arch channel formers, spaced a maximum of 15 in. apart, are attached to the spar and extend to the leading and trailing edges. Spanwise stiffeners are attached to the ribs and formers, which support the skin. All exposed wing surfaces are flush-riveted to provide smooth contours and make the plane as aerodynamically clean as possible.

The ailerons have a main spar and shear web with ribs spaced at about 12-in. intervals throughout the span. Covering is 24ST alclad sheet. While the aileron tabs are part of the aileron proper, they may be operated independently of the aileron to control balance in flight. The aileron is mounted on three hinged brackets at the rear shear web of the outer wing, so arranged that removal or assembly may be performed without removing the wing from the airplane. Total aileron weight is 89 lb, including 40.8 lb of weights.

The ailerons are statically and dynamically balanced by means of lead weights in the L.E., and trim tabs are adjusted by the pilot.

Increase in lift and drag is achieved by conventional flaps, synchronized through constant-flow valves in the hydraulic control system that permit a constant and even flow to each operating cylinder. Flaps shorten the take-off run about one-quarter and increase the glide angle about the same amount, decreasing landing speed approximately 20 per cent. The average chord is 22 in., and length 109 in. They may be

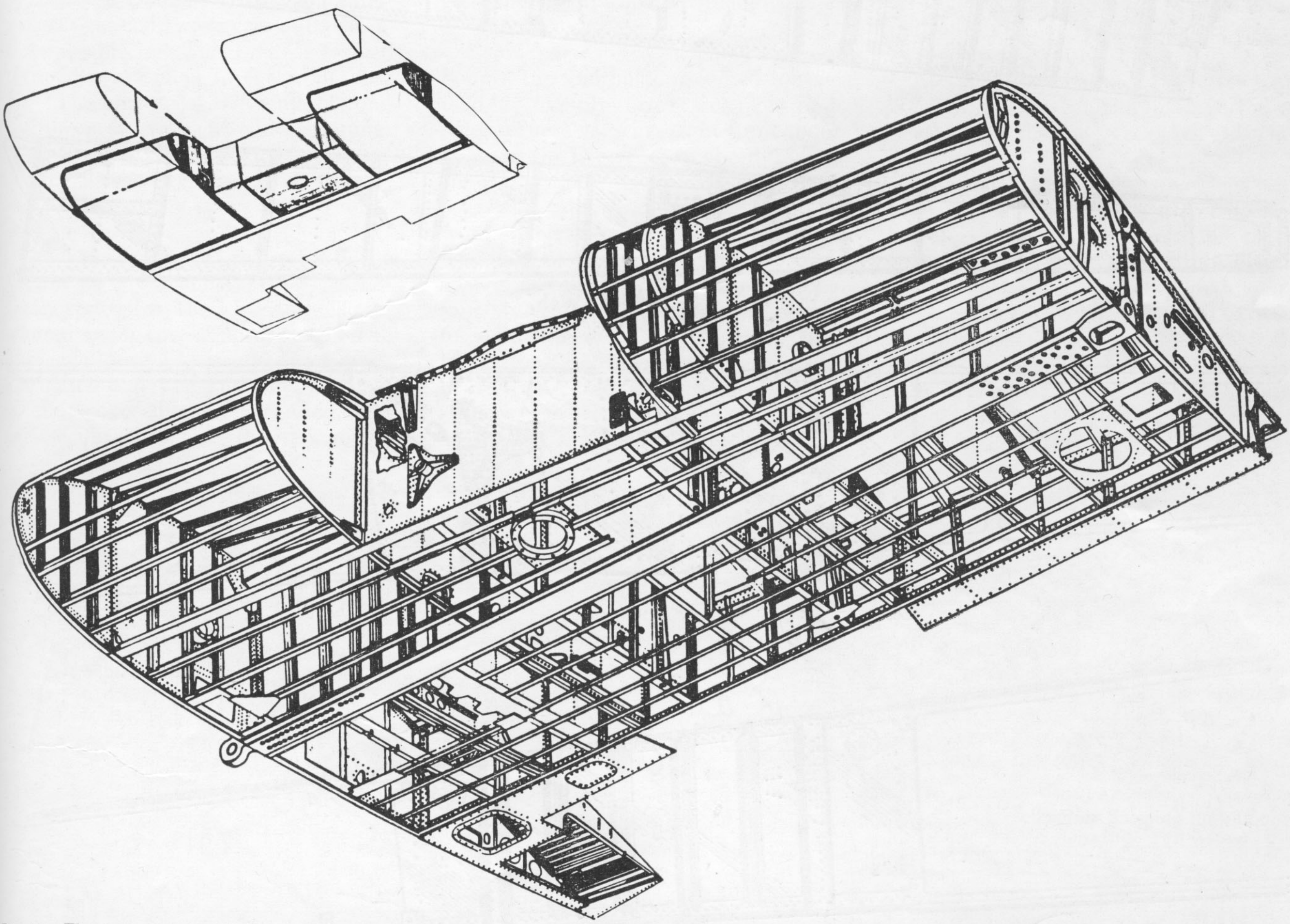


Fig. 1. The inner wing is built around a single Wagner spar and two shear webs. The spar is 38 per cent of the chord from the L.E. The rear web is 65.9 per cent from the L.E. The front web is skeleton except across the nacelle opening in front of the oil tank. The wing is fastened to the fuselage by two $\frac{7}{8}$-in. bolts at the spar, one $\frac{1}{2}$-in. bolt at the front, and $\frac{1}{2}$-in. bolt at the rear web with $\frac{1}{4}$-in. bolt at the rear of the wing. Flap hinge brackets are fastened directly to the rear shear web. The outer flap bearing of the outboard flap is in the outer wing. Fuel tanks take up the entire front of the wing except for the nacelle opening.

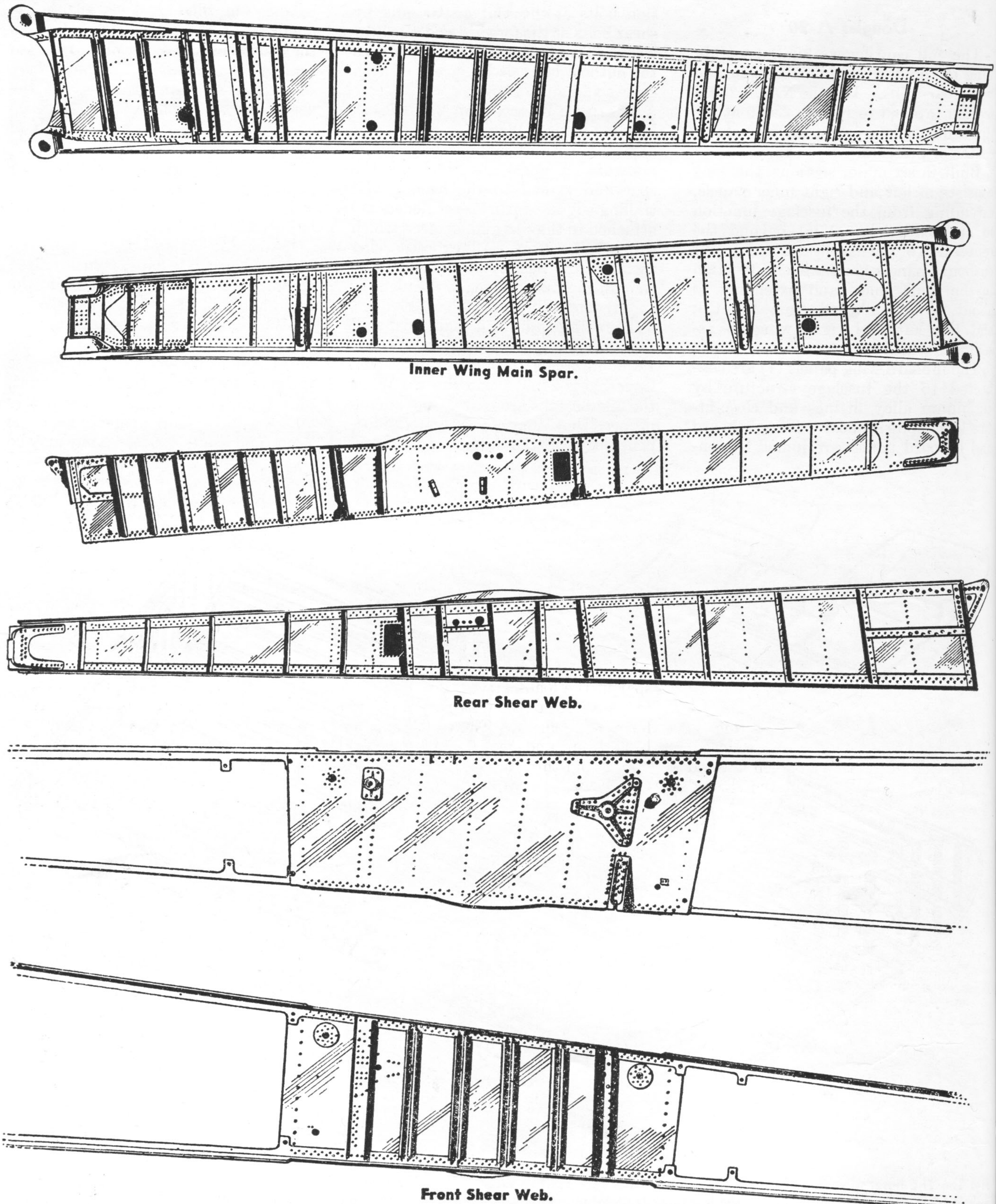


Fig. 2. Drawings show wing construction detail: (*A*) Inner wing main spar, situated 38 per cent of chord from the L.E. (*B*) Rear shear web to which the flaps are bracketed. It is placed 65.9 per cent from the L.E. (*C*) Front shear web which passes between the engine mount and the oil tank. The engine mount is bolted to the top edge.

depressed a maximum of 45 deg. For take-off under average conditions, flaps are set at an angle of 22½ deg.

The semimonocoque, all-metal nacelles have channel-type frames and extruded longitudinal stiffeners. A stainless-steel fire wall is provided between the engine and the nacelle structure. Inner wings and nacelles are built separately, then joined in the first stations of the inner wing assembly line.

De Havilland Mosquito

The Mosquito's principal load-carrying structure, the main wing, carries the engines, landing gear, radiators, gas and oil tanks, and bomb racks. It is built up as a single unit to which wing tips, leading edges, and control surfaces are added. The all-wood fuselage is lowered on top of the center section and secured by four pickup bolts and a centering bracket.

Briefly, the wing (1) from tip to tip is built upon two huge box spars with 0.025-in. plywood webs and laminated spruce flanges (2). The top of the wing is of double thickness reinforced by spanwise Douglas fir stringers sandwiched between two layers of 0.025-in. three-ply birch. The L.E. of formed plywood is attached to the front spar (3). The bottom of the wing, of composite construction, provides openings through which the tanks may be introduced. These are closed by stressed skin bolted to the spars and to adjacent ribs.

From the outermost fuel tank to the tip, the plywood underskin is permanently secured to the wing and also reinforced by spanwise spruce stringers. The complete wing is glued, screwed, and bolted together, and when finished is fabric-covered, doped, sanded, and painted until it is exceedingly smooth. The flaps and ailerons and their fairings are attached to the rear of the spar box.

Wing spar-box section varies at different points along the wing span. A typical section between the wing center and rib 6 is shown in (1). This part of the wing takes loads from the fuselage, fuel tanks, engines, and landing gear. The top section is made of two plywood panels with stringers running lengthwise between the panels. The bottom section is composed of detachable panels made as plywood-balsa sandwiches.

The top skin is of same construction as between the center and rib 6; the bottom skin is fixed and made of a single panel of plywood with longitudinal stringers.

Each spar consists of two flanges of booms, top and bottom, joined by two 0.25-in. five-ply birch webs on each side. These vary in height from about 16 in. at the wing root to about 5 in. at the end of the wing tip. In plan view, spars also taper from root to tip. The front spar varies in width from 4.37 to 1.26 in. At the bottom edges of each spar in the load-carrying section, long four-ply ash tension strips are added for reinforcement. The top flanges of both front and rear main spars are made from three laminations of 1.5-in. spruce, scarfed and spliced together vertically in the thickest section. Flanges are about 4.37 in. wide and 3.62 in. deep. They are lightened between the points of rib attachment by splindled slots about 2.12 in. deep, with 3.62-in. openings, and with 25-deg tapered sides.

The front spar lower flange is made of 0.4-in. horizontal laminations. The lower flange in the rear spar has vertical laminations in order to facilitate fabrication. The front spar is practically straight all across the wing. The rear spar, although parallel to the front one throughout the center section of the wing for about 5 ft, sweeps forward at an angle of about 10 deg on either side of the mid-section, and also upward at an angle of about 3 deg. Vertical laminations in the rear spar are more easily formed to these angles.

Metal fittings (4) form the lower rear connection between the fuselage bulkhead 3 and the lower rear edge of the rear spar.

Hardwood or bakelite packings are used on the face of the front spar to distribute pressure of the metal brackets supporting the engine and landing gear (5). On the inside of the rear spar, similar packings are provided where landing gear brackets are attached. Space between the vertical three-ply sides of the spar is filled in at each main rib, also wherever a bracket is applied. Additional vertical spacers are found at

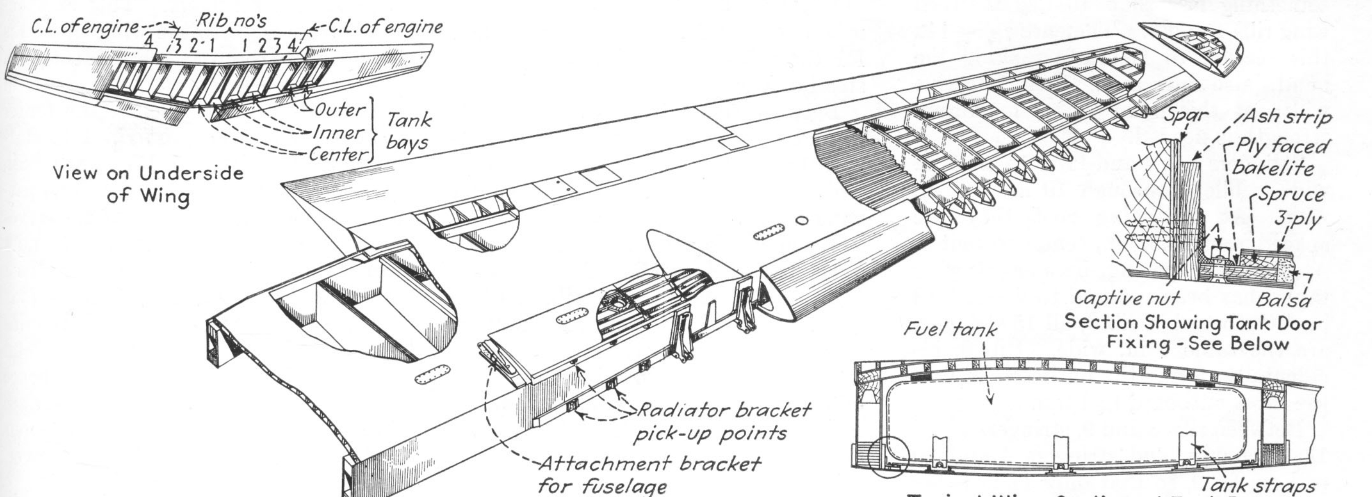


Fig. 1. Cutaway views of the wing structure, a typical section at the tank bays, and detail showing the tank door fixing.

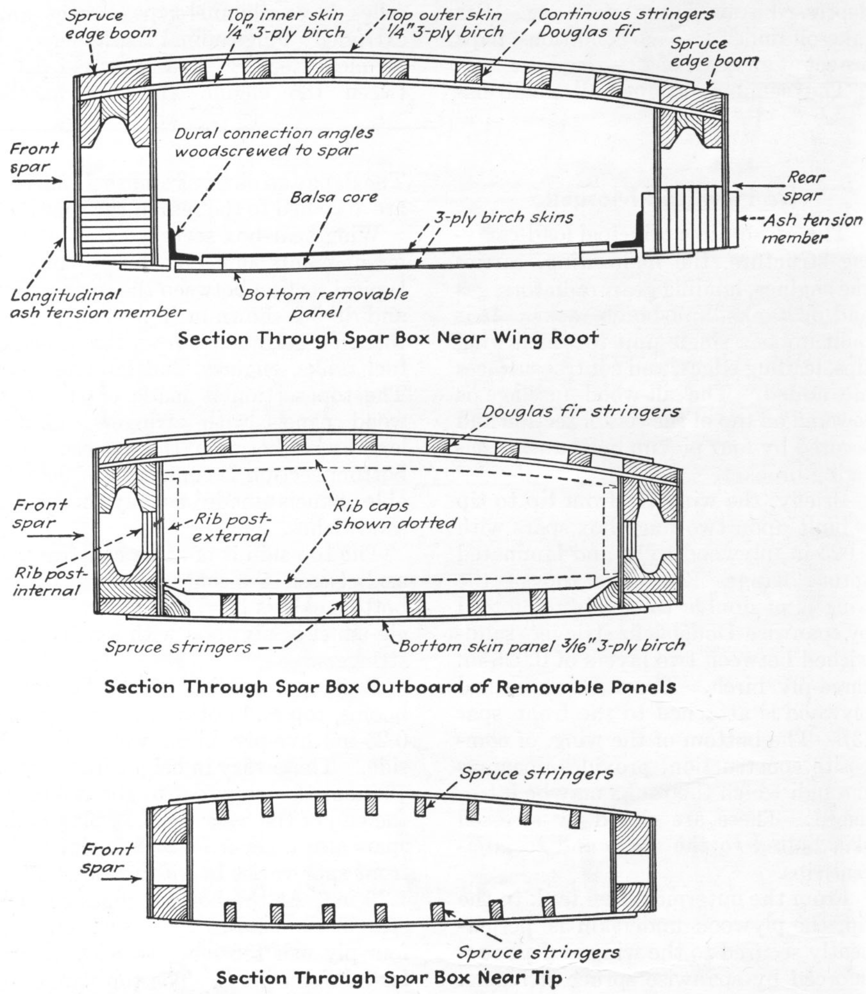


Fig. 2. Section details of a spar box at three locations: top, near the wing root; center, outboard of removable panels; and bottom, near the tip.

ribs 1, 3, 4, 6, 9, 14, and 16, and between 11 and 12. Where possible, the upper flange is spindled out between them.

The lower front flange is built up in three sections, the major one at the center with horizontal 0.4-in. laminations that extend approximately to rib 6. Then three heavier laminations are used until the spar becomes a solid piece from rib 12 to the tip. Long scarfs of ratio 1:15 are used at the transition points. One-inch-square spruce blocks are provided at the rib attachment points on the inside of the wing spars. These are screwed through the plywood to a similar block on the inside, at points where the screws do not enter either the top or the bottom boom. The ribs are glued and screwed to these spruce blocks. The plywood web grain runs diagonally when the spar is in its horizontal position.

The top skin of the wing is made up of two ¼-in. three-ply birch skins separated by 1.3-in. maximum thickness Douglas fir stringers that extend spanwise from tip to tip. At each edge there is a wide spruce boom (between the two skins) that is superimposed over each spar, thus adding to their strength.

In between the wide-edge booms, 15 narrow Douglas fir stringers are equally spaced. At the wing center section they are parallel to one another, but outboard of the fuselage, although equally spaced, all incline together at different angles. For reference purposes they are numbered from 1 to 15, 1 being the first aft of the front edge spar.

These stringers have to be bent at something less than 10 deg between wing ribs 1 and 3. They are spliced in this section to facilitate making the bend, also increasing their effective width at this point where maximum strength is needed.

Stringers 1 to 4 and 11 to 15 are 1 in. wide, while 5 through 10 are 1.6 in. wide. At the wing root they are spaced about 4.37 in., center to center. At rib 3 the spacing, because of wing taper, has been reduced to about 3.82 in. Outboard of rib 6, all 15 stringers are the same 1 in. wide. Rib 6, incidentally, forms the outboard wall of the most outboard fuel tank.

Between ribs 8 and 9, stringers 7 and 13 terminate, and stringers 4 and 10 end on rib 9, so that only 11 pass beyond this point. At rib 11, all stringers have been reduced to 1-in. thickness and 0.75-in. width. At this point the 1- by 0.5-in. stringers start, and spacing is about 2.30 in. Spruce is specified for the 0.75- and 0.5-in. stringers instead of Douglas fir.

Between ribs 13 and 14, stringers 1, 6, and 12 terminate; between ribs 14 and 15, stringers 3, 9, and 15 stop. This leaves 2, 5, 8, 11, and 14 to end on wing-tip rib 16.

Wood blocks separate the stringers over ribs 1, 3, 4, and 6, and the top skin is bolted through to the rib at these points. Elsewhere, top and bottom skins are screwed to the stringers after gluing. Screws are put in at intervals of 3 in., upper and lower skin screws being offset 1.5 in. to distribute the load evenly and prevent interference. At ribs where there are through bolts, the screws are omitted.

The single underskin, 0.187 in. thick, is made from three-ply birch reinforced with spruce stringers. This skin extends from rib 6 to the wing tip and is glued and screwed permanently in place.

Bomb-bay doors enclose the center wing section from port rib 1 to starboard rib 1. From rib 1 outward, both sides of the wing follow the same pattern so that a description of one serves both. The space between ribs 3 and 4 forms the wheel well. Between ribs 1 and 2, 2 and 3, 4 and 5, 5 and 6, four fuel tanks are suspended from the ribs on each side of the main wing. Metal fairing encloses the landing gear, hence this portion of the wing bottom surface does not have to be covered. The four fuel-tank access openings, however, must be closed.

One cover panel serves to enclose the two fuel-tank openings inboard of the

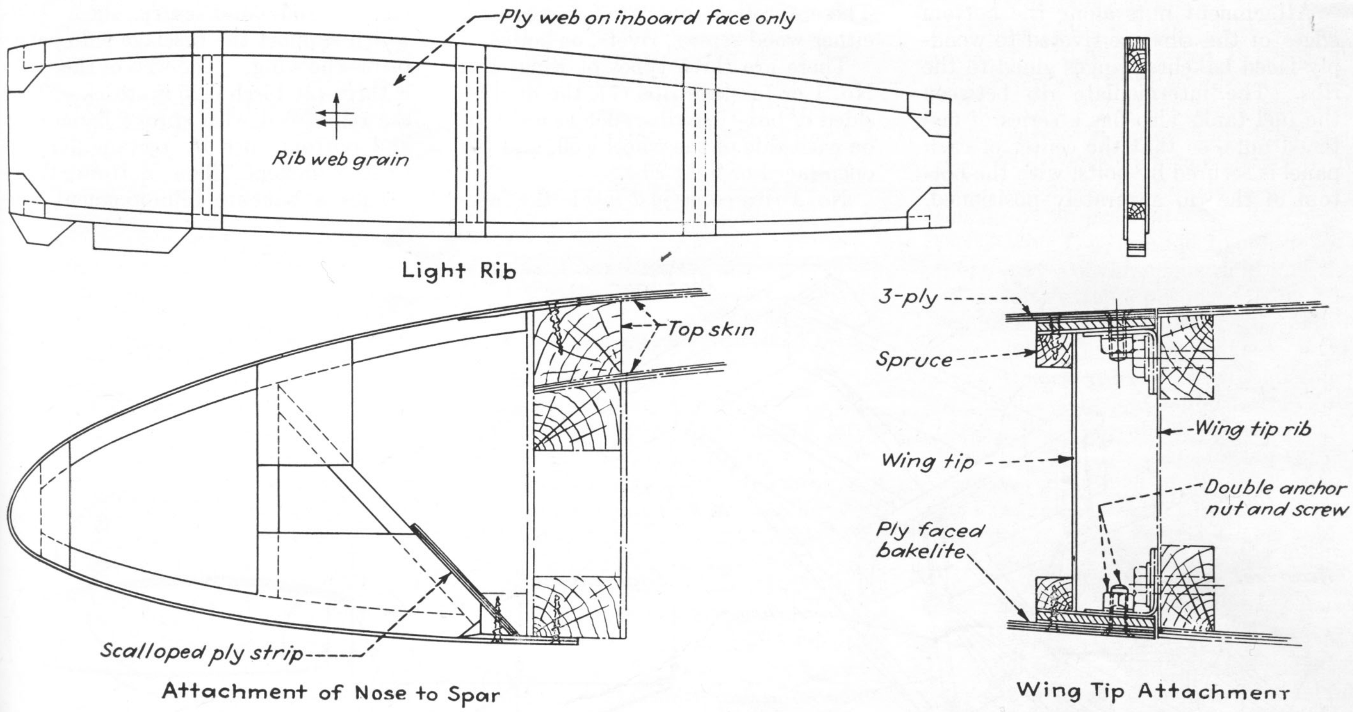


Fig. 3. Light ribs and attachment of the L.E. and the wing tip.

wheel well; a similar one protects the two outboard tanks. These give a perfectly smooth bottom to the wing where they are attached, since flush screw-heads are provided, and the edges are faired into the wing.

Tank-bay covers, like the fuselage, are plywood and balsa sandwiches. The main constructional feature is the use of laminated fabric-reinforced bakelite sheets having a 0.050-in. birch veneer facing for the bolting strips. This permits gluing bakelite to the edges of the tank-bay panels and to the bottom skin of the wing where the bolted joint is made.

The bakelite has a bearing stress value of 35,000 psi and provides a non-crushable bearing for the attachment screws. For further protection and strength, alclad lap plates are provided, with three rows of countersunk bolt holes for the joint along the edge of rib 6 (6). The nuts are held captive with metal covers riveted to structural rolled-aluminum angles. These angles are fastened to the inside faces of the front and rear spars by wood screws. The angles are made up 1 ft in length, and each carries four fastened nuts. Dividing these angles in sections allows for any expansion or contraction of the wood. The angles are mounted in the 3.0- by 0.5-in. ash tension members at the lower edge of each wing spar.

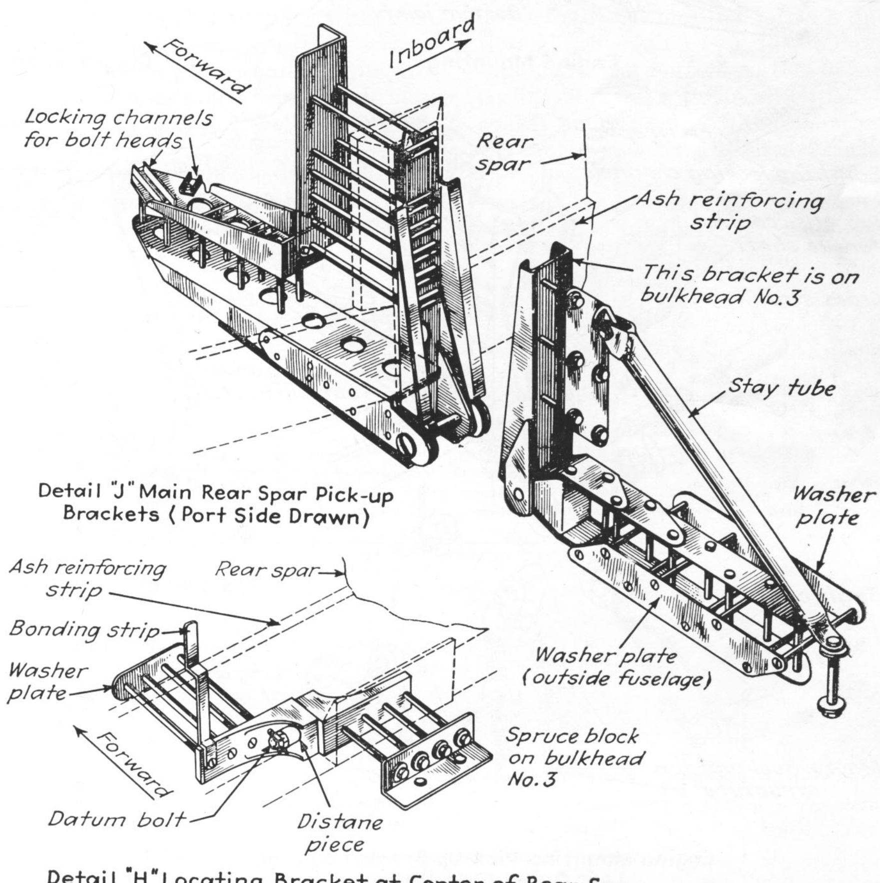


Fig. 4. Metal fittings which form the lower rear connection between fuselage bulkhead 3 and the lower rear edge of the rear wing spar.

Attachment nuts along the bottom edges of the ribs are riveted to wood-ply-faced bakelite flanges glued to the ribs. The intermediate rib between the fuel tanks also has a series of fastened nuts, so that the center of each panel is secured by bolts, with the bottom of the rib accurately positioned. These Aerotight nuts are fastened with either wood screws, rivets, or bolts.

There are three types of wing ribs: No. 1 or fuselage ribs (7), the double-sided or box-type ribs, such as are used on each side of the wheel well, and the open-faced or light ribs.

No. 1 ribs come just inside the fuselage contour and carry shear bolts which support the fuselage side panels below the wing. The web of these ribs is three-ply birch 0.25 in. thick. They are reinforced with spruce flanges top and bottom, also by rectangular vertical stiffeners. The bottom flange carries a bakelite reinforcement con-

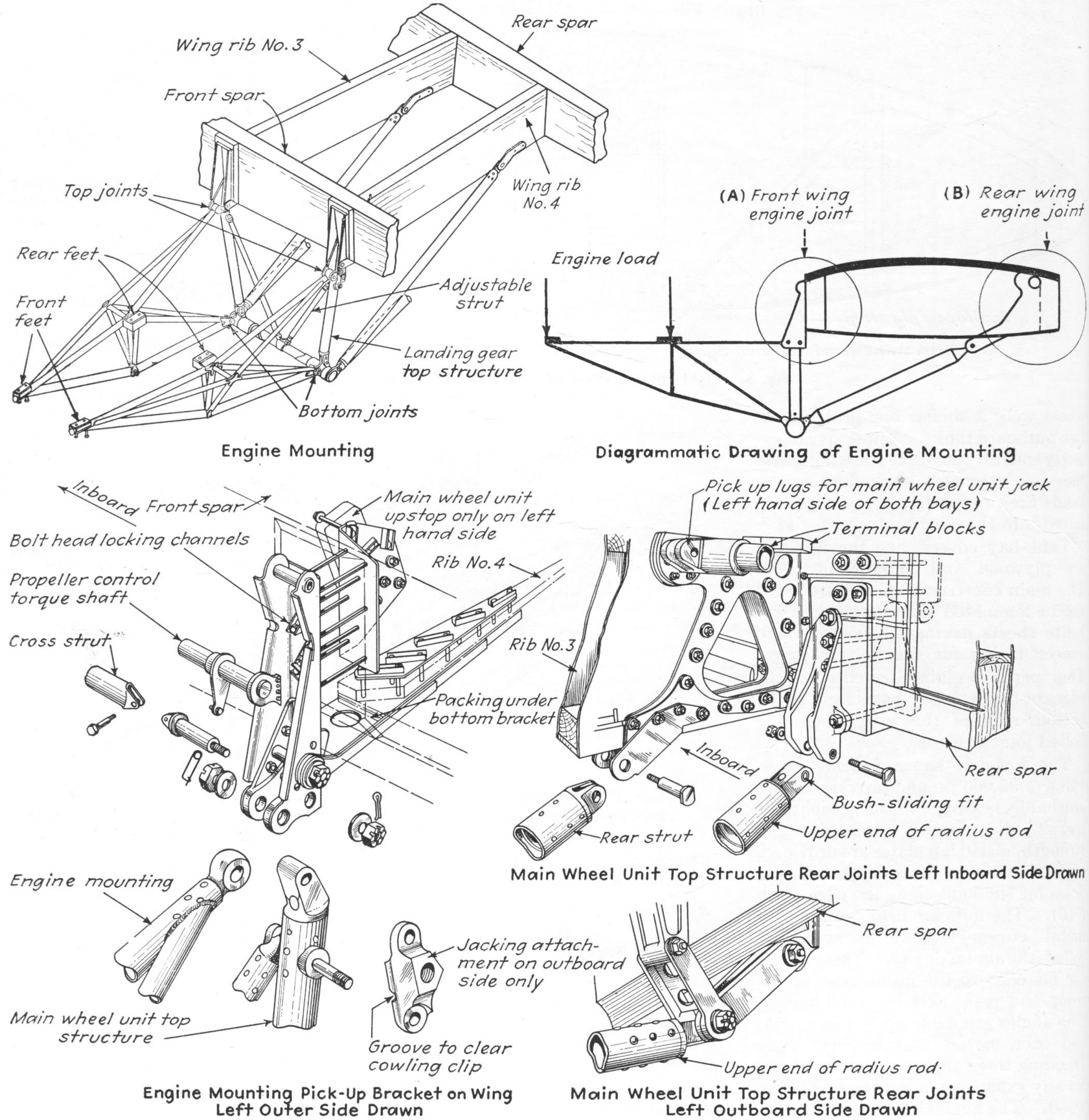


Fig. 5. The engine and landing gear supports form a light, rigid frame, bolted through spars and ribs to spread the load and stresses through the structure.

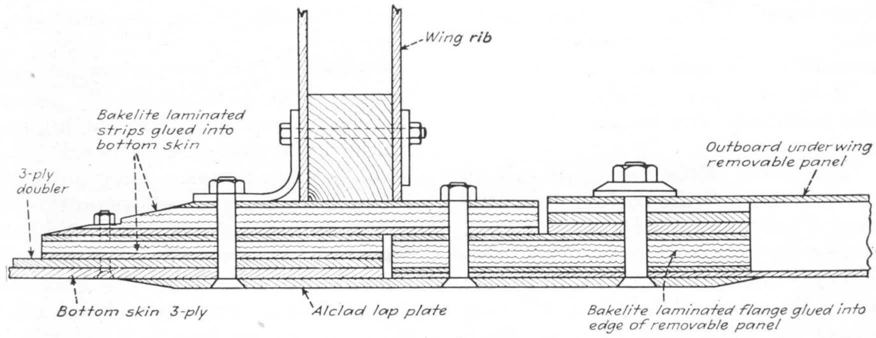


Fig. 6. Detail of the tank bay panel attachment at rib 6, where alclad lap plate is used.

nection strip, to which the inboard edge of the inner fuel tank cover panel is bolted. The box-type ribs are made with two 0.187-in. three-ply birch sides and have walnut, birch, ash, or spruce stiffeners, depending on their location and purpose. Engine rib 3 is typical (7). The stiffeners are all Grade A spruce, and except for the top one, they are all solid. The top flange is made from 0.27-in. spruce laminations and is about 0.8 in. deep over its full length. The lower flange averages 1.3 in. deep. The solid spruce vertical stiffeners are 0.4 in. wide. The outside width of the rib measures 2 in. Semicircular cutouts are provided in the side panels through which the Aerotight nuts can be inserted. Bolts that go through the upper double skin catch the nuts inserted in the top flange of this rib. Nuts holding the lower panel are inserted through similar holes in the web above the bottom rib.

To distribute the load, the cutouts are alternated, first on the left web then on the right. Boltholes are spaced about 3 in. apart. Spacing of the screws that clamp the rib stiffeners and side panels together is also kept at about 3 in. Ply-faced bakelite is glued to the bottom to carry the tank panel fastening nuts. These are omitted on double panels where they bear against underskin stringers instead of against a tank door.

Single web ribs are made in two weights: those for ribs 7, 8, 12, 13, and 15, have a three-ply 0.0625-in. web; the others have 0.078-in. webs. All are made of three-ply birch with the web located on the inboard face. The top and bottom flanges are solid spruce. The lower one varies in depth from 0.6 to 0.7 in. by 0.7 in. in width. Top flanges vary from 0.97 to 0.65 in. in depth. The 0.4- by 0.7-in. vertical stiffeners are each reinforced by a 1.4- by $\frac{1}{16}$-in. three-ply piece glued and bradded to the exposed side. Triangular gussets, also of three-ply birch, are provided at rib corners.

There are 16 ribs on each wing, not counting the double-sided box-type rib located at the center of the ship. The latter is used to help support the bomb racks. The ribs on each side of the fuel tanks and wheel wells are of the box type. There are also two other box-type ribs, 8 and 14. These are located at critical points, the first where aileron control reactions take place, the latter at the outboard aileron support.

Wing tips are bolted in place just like the tank bay doors, with flush screws that engage captured nuts on wing rib 16. These nuts are held by an aluminum cuff bolted to the wing end rib. The wing tip has a spruce and laminated plywood rib that matches the wing and rib. The feature of this construction is the provision of ply-faced bakelite reinforcements all round the attaching point so that screws will not crush the tip or wing end at the joint when they are tightened up.

The wing tip itself is constructed with a plywood outer skin glued and screwed to spruce formers and to a triple laminated spruce edge that gives the tip its proper contour.

The wing L.E. is made up of four sections. Two of these, one right and the other left, extend outboard from the engine nacelle to the wing tip. They are slipped over the forward side of the front wing spars and screwed and glued in place. When assembled, they become a fixed portion of the wing unit. Each L.E. consists of a series of spruce nose ribs reinforced by three-ply wood gussets and a longitudinal scalloped plywood strip set in at a 45-deg angle. This structure is then covered with a preformed plywood skin that fairs into the top and bottom skins of the wing.

The second section of the L.E. between the engine and fuselage has been developed so as to form a housing for oil and liquid coolant radiators. It is built of 24ST alclad sheet. The L.E. has a fixed opening that forms a duct through which air passes to the radiators. The rear bottom portion of each cooling unit has a two-position flap to control air flow through the radiators.

Trailing-edge flaps located between the inboard end of the aileron and the fuselage are in two sections connected by a torque tube with hinges at each

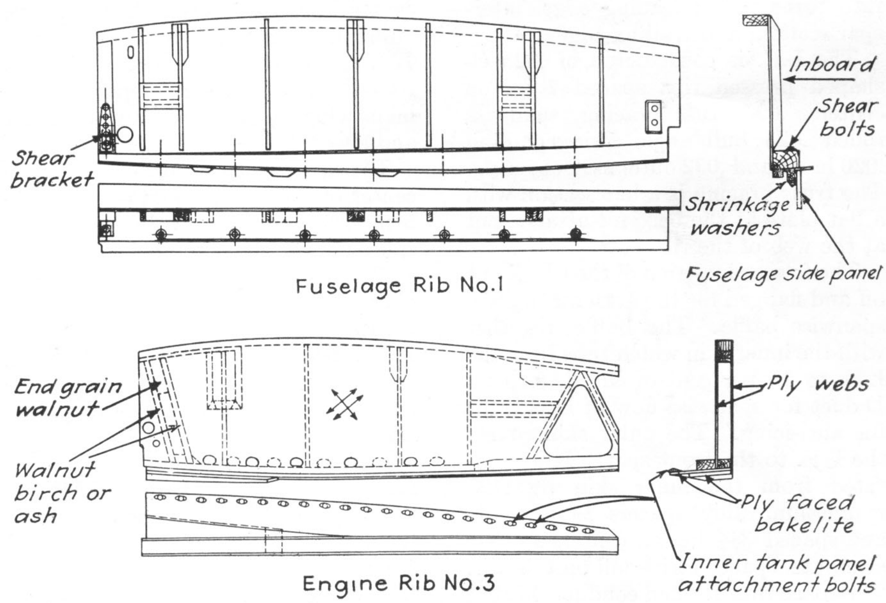


Fig. 7. Details of fuselage rib 1 and engine rib 3.

end and in the middle. They are constructed with spruce tips reinforced with plywood.

Finished flaps have a three-ply with skin, the dual grain running longitudinally. Attached to the rear spar, the operating jack moves the flaps by a direct connection at the center to the flap-operating arm. Control reactions are taken by the rear spar almost immediately behind rib 3, where the greatest resistance to deflection can be obtained. A rubber tube seal at the bottom of the flap prevents any air leakage through the hinge during flight.

The aileron is built upon 24ST alclad spar of channel section. The ribs, except those for hinges, are all of skeleton form, 24ST alclad. The entire assembly is covered with 0.012 24ST alclad skin. The tab, also of alclad, is attached to the aileron's inner end by a piano hinge. It is automatically operated by an adjustable linkage at the inboard hinge. Mass balances are provided in the aileron L.E., which is supported by three hinges, the outer and inner ones of which are universal so that there can be no misalignment in assembly or in service.

Tabs are differentially controlled, the port one being trimmed from the cockpit.

The wheel doors are contoured to enclose the nacelle bottom from the engine fire wall back to the rear spar. Doors are made from two sheet-aluminum stampings riveted together along the edges. There is a stiffening rib at the front hinge section. Each door is supported by two invisible-type hinge brackets. The lower edges have a 0.5-in. rubber tube to provide a seal. Front and rear ends fit over canvas sealing pads riveted to nacelle panels.

In operation, the rear ends of the doors are drawn together by spring-loaded 0.18-in. flexible steel cables and are opened by tubular steel guards attached to the landing gear leg as the wheel is lowered. After the door ends are cleared by the legs, the tubes attached to the sides of the lower radius rods catch bakelite rubbing strips on the bottom edge of the doors and keep them apart.

Flexible, 0.18-in. steel cables are used to pull the doors together. These are attached through turnbuckle adjustments to the cross piece between diagonal leg cross braces. They are then led back to a pair of pulleys on the radius-rod cross-member tube, and forward again through bronze fair-leads in the cross piece to which the ends are first attached. From the fair-leads the cables pass over long bakelite rollers attached to the front of the compression legs, and thence into front end of the wheel doors guided between a couple of plastic sheaves.

The cable end is attached by eye splices to the end of a ⅜-in. bungee, which is led around a pulley at the rear of each wheel door and back to the front end of the door.

When the doors are open, the bungee is stretched almost double its original length. This structure permits keeping the doors under tension at all times, whether open or closed.

Fairchild C-82 Packet

Consisting of a center section and two outer panels, which include an integral anti-icing system, the C-82's wing is an inverted gull type of full cantilever, tapered all-metal design. The airfoil combination is based on NACA sections incorporating washout determined to prevent wing tip stalling.

Extending to just outboard of the nacelles, the center section (1) is divided into three parts: leading edge, interspar section, and trailing edge.

The L.E. is constructed of .025 C-shaped pressed ribs spaced 7 in. on centers, .025 truss bracing, spanwise rolled .025 bulb-angle stringers, and .020 inner and .032 outer skin covering. The truss bracing is a hat section with a flat plate at the base for attachment at the web of the rib.

The forward portion of the ribs is cut off and flanged for the attachment of a spanwise baffle. The baffle, together with the inner skin which runs from the L.E. to 15 per cent of chord, forms a D duct for spanwise flow of heated air for anti-icing. The outer skin covers the L.E. to the front spar. It is separated from the inner skin by .125 magnesium alloy spacers ½ in. wide and spaced 3½ in. on centers so that alternate spacer strips fall on the ribs. The space thus formed conducts heated air chordwise in the D duct.

The interspar section is built of front and rear parallel spars, interspar ribs, and top and bottom surfaces. The spars are of conventional web with extruded upper and lower chord members and rolled vertical stiffeners to which ribs are fastened. The front spar is approximately 38 in. deep at the center line and tapers to about 27 in. at the outer wing panel attaching point outboard of the nacelle.

The rear spar is 31 in. deep at the center line, tapering to 22 in. at the outer wing fitting. Spar spacing is 72 in., continuous to the tip splice. At each end of the interspar section, main wing hinges are bolted to upper and lower chords.

The spar web is continuous at the center of the section, and chord members are joined by bolted extruded splice plates. The web is .040 for 63 in. each side of the center line, and beginning 52 in. from the center line, the thickness is increased to .064 out to 174 in. from the center line by utilizing a lap splice. Thus, between the inboard and the outboard fuselage fittings, the spar web is .104 thick.

Fuselage fittings—14ST forged channels with ¼-in.-thick base, and 5/32-in.-thick outstanding legs—extend from the upper to the lower spar chords, and are riveted to spar webs. These fittings—one at each main attachment point on the front and rear spars—each carry four bolts and afford a total of 16 bolts to take full fuselage load. The bolts are ⅝-in. Fairchild standard, equivalent to NAS bolts dimensionally and in strength characteristics but having exceptionally high fatigue life.

The interspar ribs are .025 web beams, spaced 21 in. on centers, and have rolled chord members and hat-section stiffeners. The web ribs are utilized to form side supporting members for the bladder-type fuel cells carried in the center section. Provision is made in the ribs to accommodate fuel-cell interconnecting fittings.

Two compression ribs in the nacelle are spaced about 44 in. to permit housing of the landing gear. The ribs are double-web box beams with .051 webs spaced by .064 channel members, and .072 channel chord members on the webs are decked by .064 plate. Forged and cast fittings are internally mounted on the compression ribs to accommodate anchor points for the nacelle steel structure and the landing gear structure.

The top surface of the interspar section is built of spanwise trapezoidal hat-section stiffeners and heavy-gauge outer skin. Stiffeners are 75ST varying from .125 to .040 from front to rear spar, and at the center line are spliced with bathtub fittings and tension bolts (2). Skin between spars is lap-spliced 24SRT (heat-aged to afford high

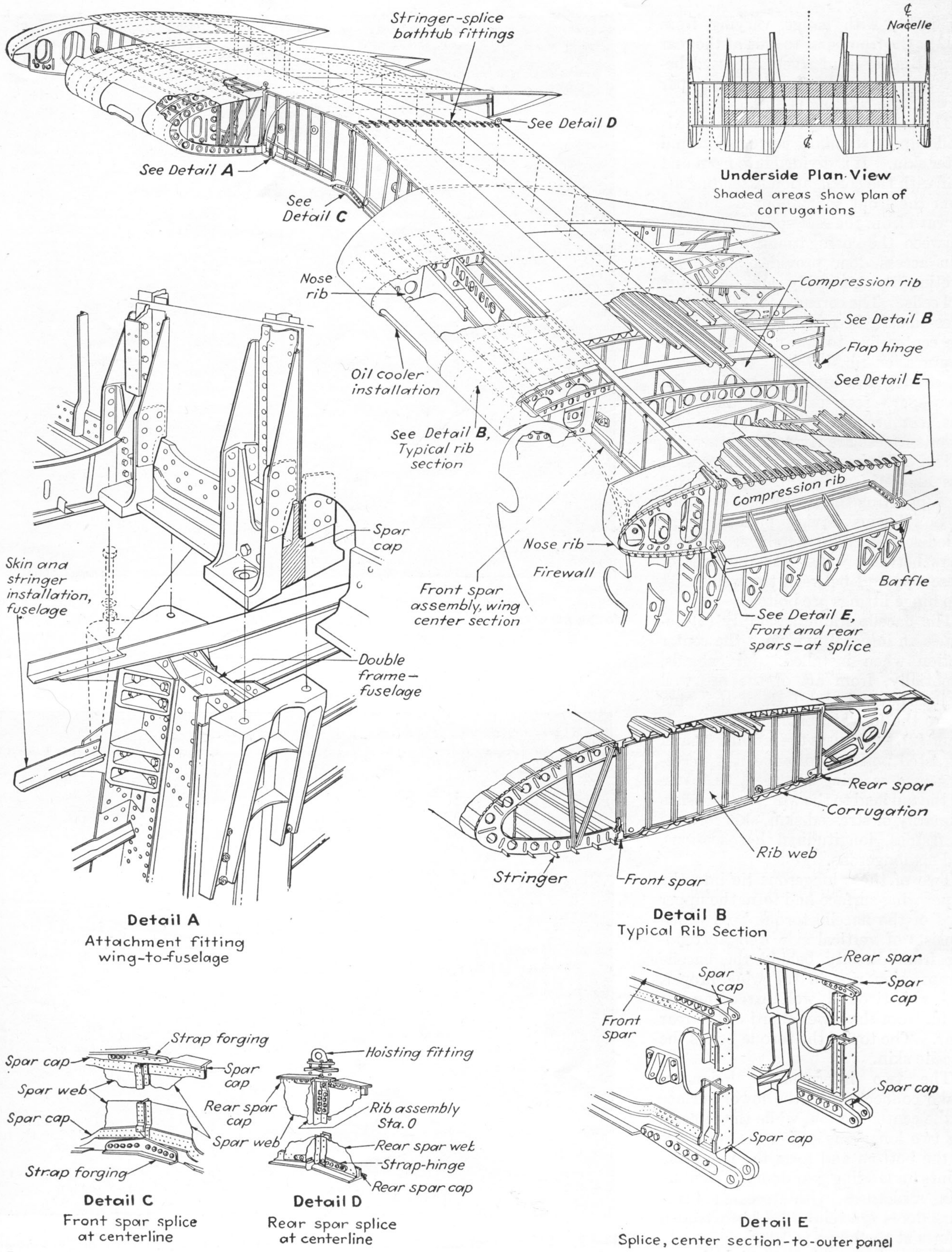


Fig. 1. Structural details of the wing center section. The underside plan view at the upper right shows corrugation areas (shaded). The wing-to-fuselage fitting is being replaced by a forged channel.

strength), with gauge varying from .102 at the front spar to .064 at the rear spar. Brazier-head rivets are used between spars, and from the front spar forward the riveting is flush.

The interspar section lower surface is made up of standard corrugation and outer skin. It is divided into front and rear with the corrugation extending aft from the front spar about 24 in. and forward from the rear spar about 28 in. Between the corrugations, a stressed-skin access door provides means for riveting the assembly and installing fuel cells. The corrugated sections and stressed-skin access door extend from the center line to the nacelle inboard compression rib, 147 in.

Forming the interspar section, the front-spar, rear-spar, and interspar ribs, compression ribs, and top and lower surfaces are riveted together.

The T.E. has conventional pressed ribs and stiffened skin. Special ribs for supporting the flap hinges are built as box beams having pressed webs, rolled-section chord members, and stiffeners between webs. At the ends of these ribs and between the webs, cast flap hinge fittings are bolted.

The nacelle frame assembly (4) becomes an integral unit with the center section when installed, and extends, essentially, from aft of the fire wall to just beyond the T.E. of the wing where the forward boom connection is made (2). It houses the landing gear in retracted position, provides the necessary load-carrying members to transfer the tail load to the wing, and consists primarily of stressed skin, skin formers or frames, longitudinal hat sections, and six longerons.

Two of these longerons tie into the upper wing surface and form the upper caps of the nacelle torque box, which consists of vertical side webs, extending from directly behind the nacelle compression ribs in the wing proper, and a horizontal web extending aft 60 in. from the lower chord of the rear spar. The top of the torque box is the nacelle skin.

The two intermediate longerons make connection to the lower surface of the center section, while the remaining two longerons stiffen the structure at the bottom and form the mounting points for landing gear doors. Double-skin structures with recessed inner skin, doors are reinforced by extruded frames at the hinge points.

The upper and intermediate longerons are .102 and .072 high-strength

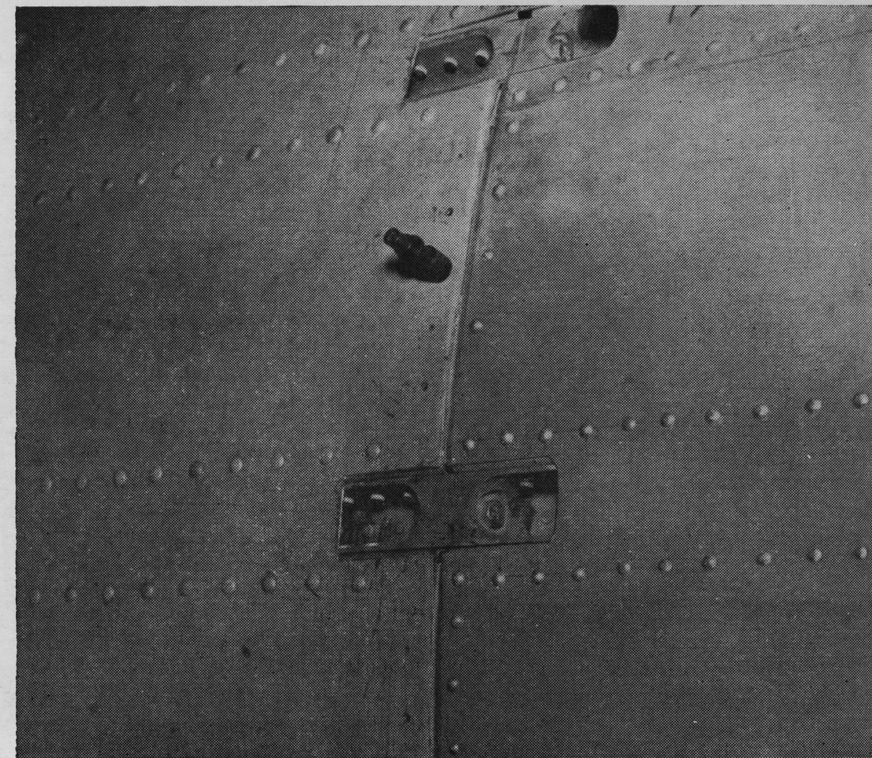


Fig. 2. Seen here are bathtub fitting and tension-bolt connection for joining the boom to the nacelle.

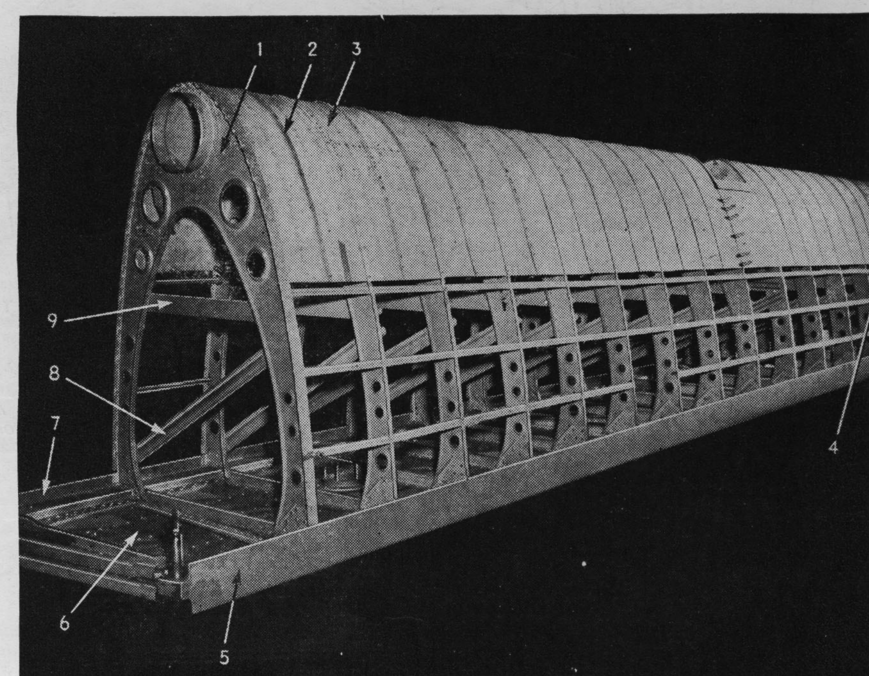
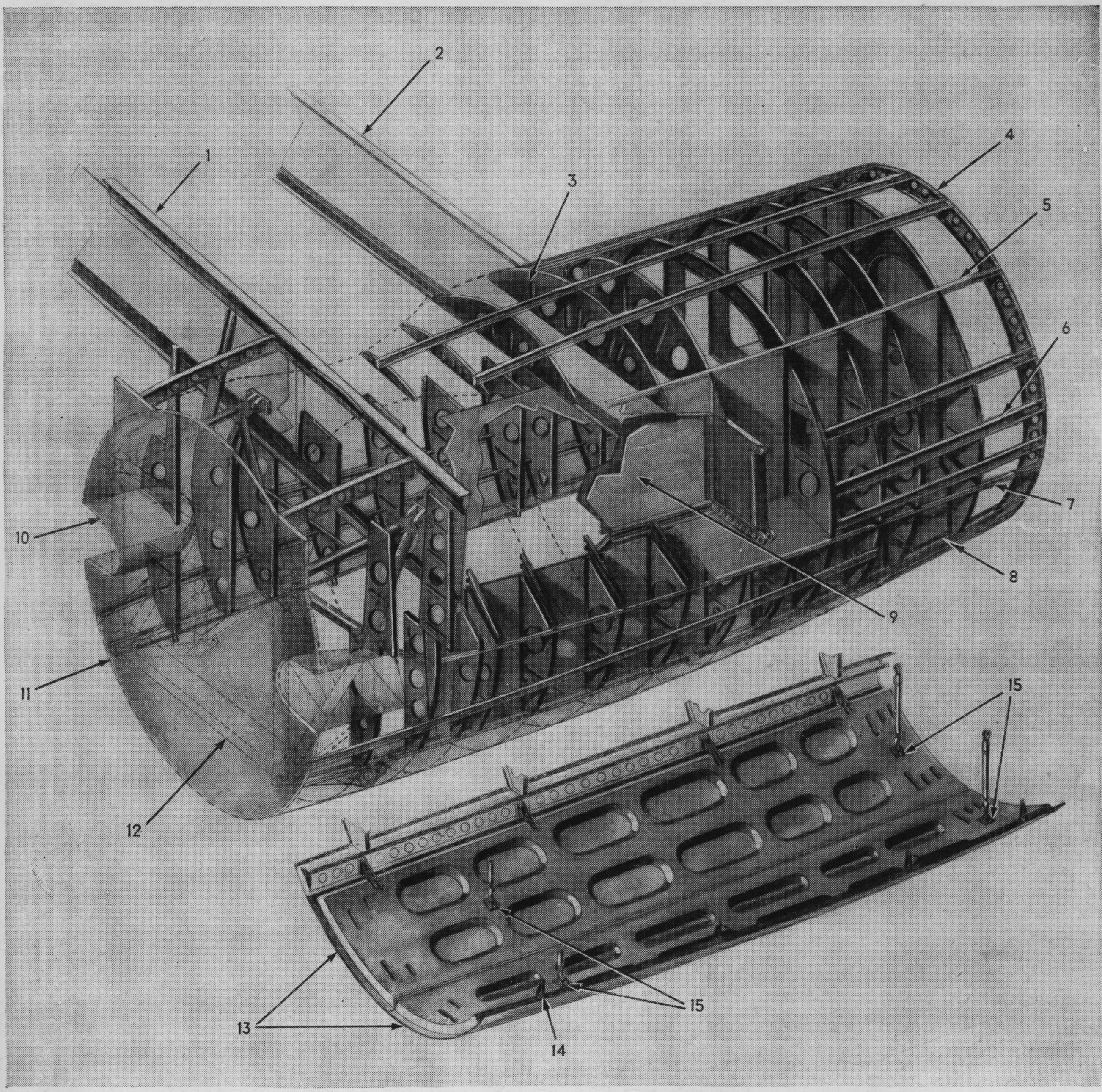


Fig. 3. Outer panel L.E.: (1) nose rib; (2) magnesium spacer; (3) inner skin; (4) bulb-angle stringer; (5) front spar upper chord; (6) spar web; (7) lower chord; (8) truss member; (9) pleat under the truss member.



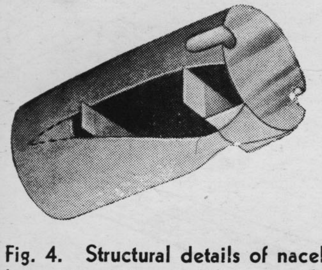


Fig. 4. Structural details of nacelle frame assembly: (1) front spar; (2) rear spar; (3) former; (4) end frame; (5) upper longeron; (6) hat-section stringer; (7) intermediate longeron; (8) lower longeron; (9) compression rib; (10) exhaust well; (11) fire wall; (12) nacelle structure steel tubing; (13) landing gear doors; (14) hinge; (15) operating rod bracket. The outline sketch at the left shows skin installation.

R301T alloy, respectively; lower longerons are .125 24ST, with .072 doubler added.

The L.E. and T.E. and nacelles are riveted to the interspar section to form the center section structural assembly.

Provisions are made for mounting oil coolers, cooler inlet ducts, engine controls, fuel, oil, hydraulic, instrument, and fire-extinguisher lines, and electrical wiring, within the L.E. The T.E. encloses the flight controls.

The outer wing panel construction (5) is generally similar to that of the center section. The L.E. (3) has double-skin construction for anti-icing, and the interspar section has similar ribs in the region of the outer fuel cells. Outboard of this area, the interspar ribs are .025 hydropressed webs with flanged holes and stiffening beads and .064 rolled angle chord members.

Standard corrugation and outer skin composes the upper surface. The corrugation varies from .102 at the front spar inboard end to .032 near the tip, and extends between spars for about two-thirds of the span, thence tapers to a width about 8 in. at the front spar near the tip. Where the skin is not stiffened by corrugation, .032 and .040 Z-section stringers are used.

The lower surface also is formed with two-section corrugation externally covered with skin, and a center-access stressed-skin door is located in the region of the fuel cells. Corrugation varies from .051 at the inboard end to .025 at the end of the corrugation about midway along the outer panel, and is tapered from the end of the access door to the halfway point.

Between the end of the corrugation and the wing tip, the lower surface is stiffened by intermediate chordwise .025 hydro-pressed formers and spanwise .032 hat-section stringers.

Details of the center section to outer

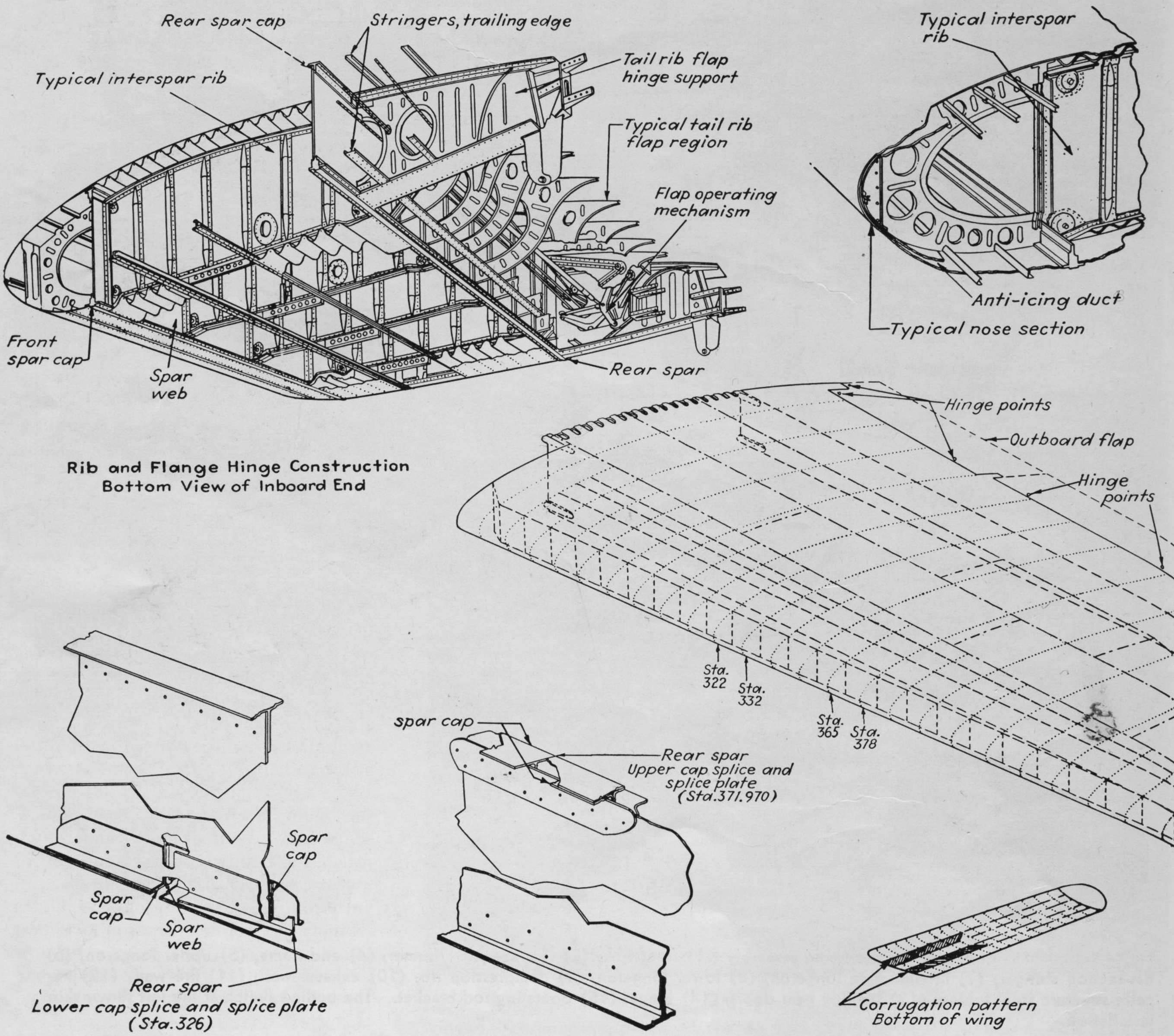


Fig. 5. Structural details of the wing outer panel.

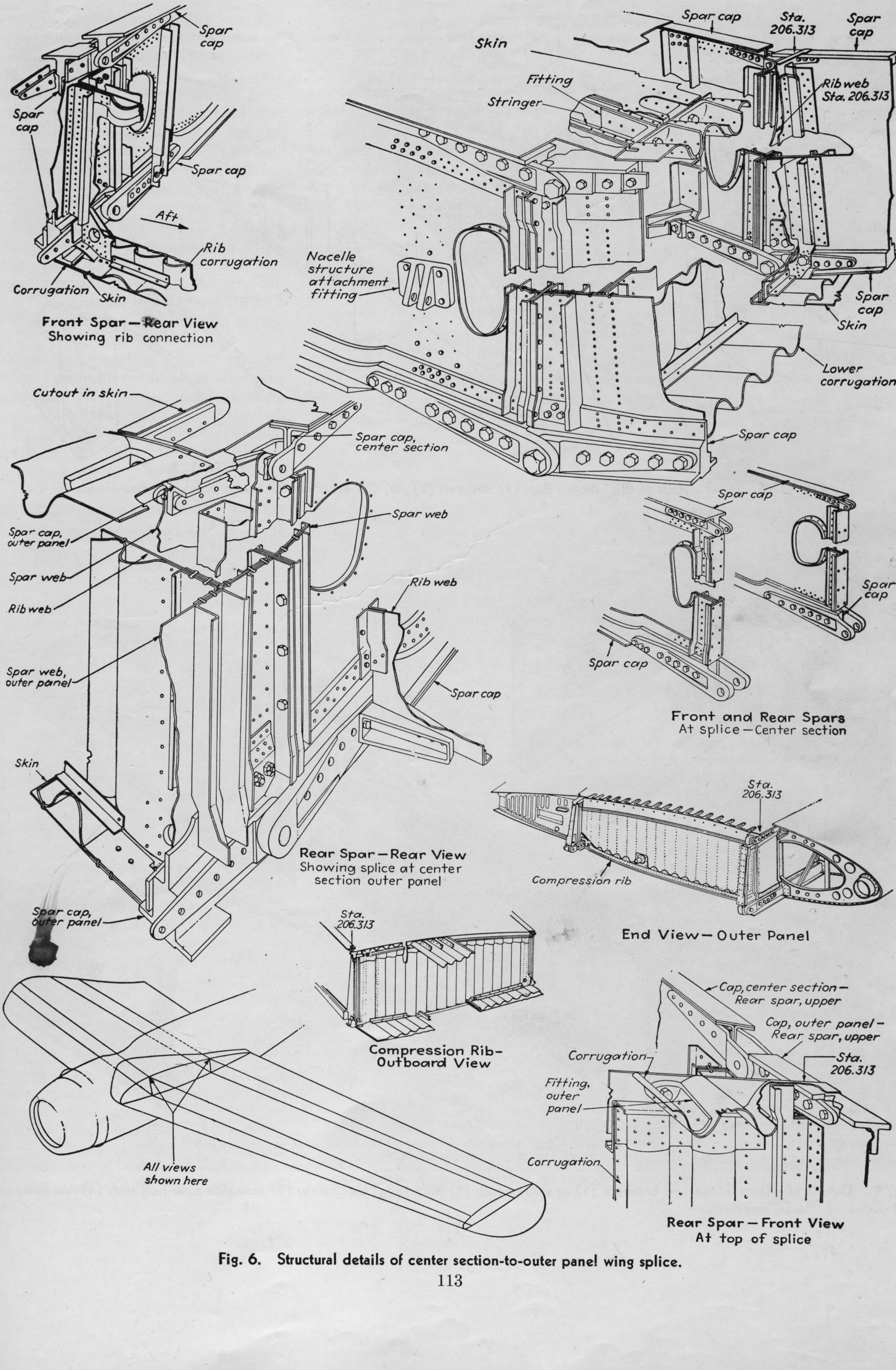


Fig. 6. Structural details of center section-to-outer panel wing splice.

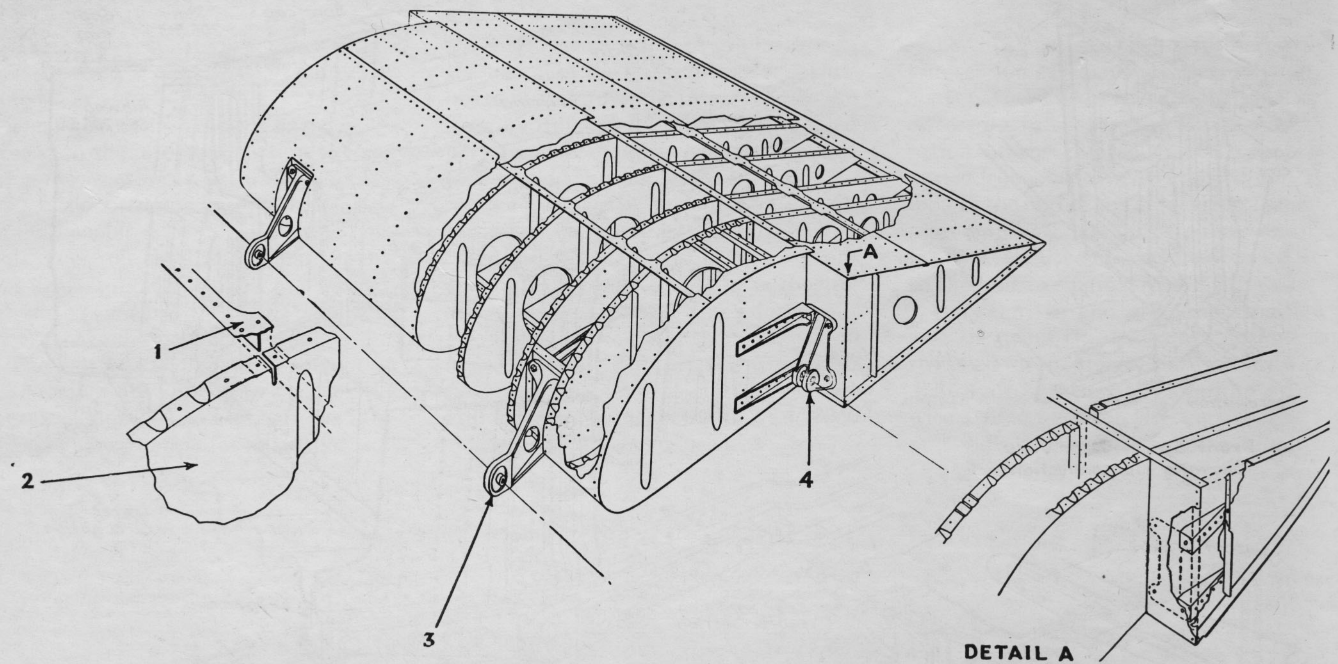


Fig. 7. Structural details of the inboard flap: (1) stringer; (2) rib; (3) actuator attachment point; (4) flap hinge.

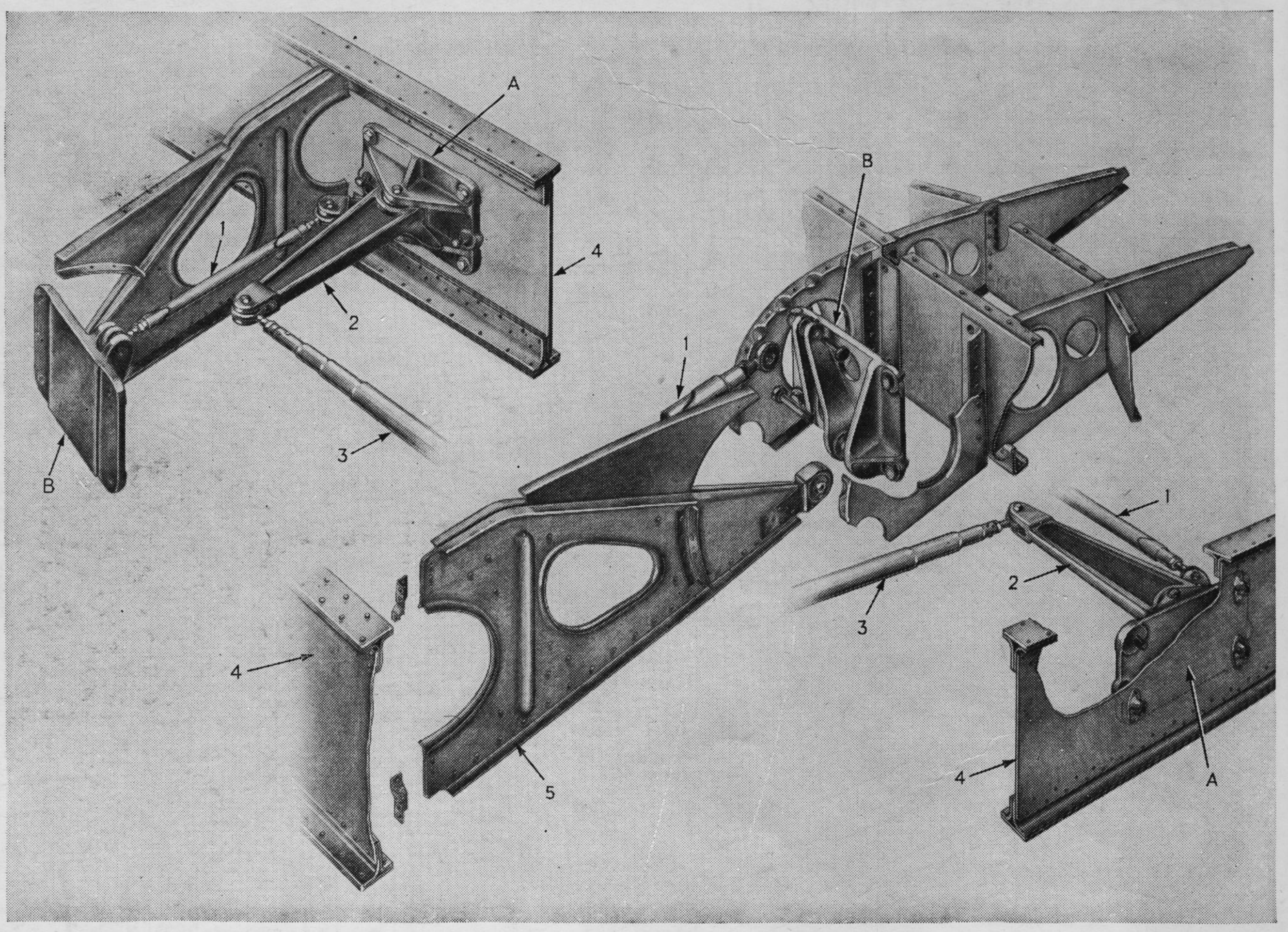


Fig. 8. Details of aileron hinge and brackets: (1) operating rod; (2) differential bell crank; (3) spanwise push-pull rod; (4) rear spar; and (5) outboard aileron hinge rib.

panel wing splice are pictured in (6).

Extending for about 25 per cent of the chord, wing flaps are NACA slotted type and are built of pressed ribs and spars, the latter together with the L.E. skin forming the main structural element. The inboard flaps (7) are approximately 5 ft 10 in. long, and the outboard flaps are about 7 ft 8 in. Each is attached to the wing by two hinge points at the spar end and two actuating points on the L.E. Connection is made with ball-bearing links arranged so that flap motion is, first, almost horizontal, then continuing aft with little angular deflection. As flap motion continues, angular travel increases rapidly to a maximum deflection of 40 deg. Operation is by an electric motor, located in the fuselage aft of the rear spar, through the medium of a screw-and-nut type actuator connected to the flaps by a system of bell cranks and rods (8). In an emergency, the flaps can be lowered by a handcrank.

The aileron structure consists of an inboard and outboard unit (9), the former measuring about 13 ft 7 in., and the latter, 11 ft 4 in. They have pressed channel spars, pressed ribs, and metal skin to form the main structure, and pressed tail ribs. The entire assembly is fabric-covered.

The inboard and outboard ailerons operate as a single unit. The inboard also is fitted with a droop actuator to lower it with the flaps when the latter are in landing position. This provides additional effective flap area and still permits full operation of the ailerons as such.

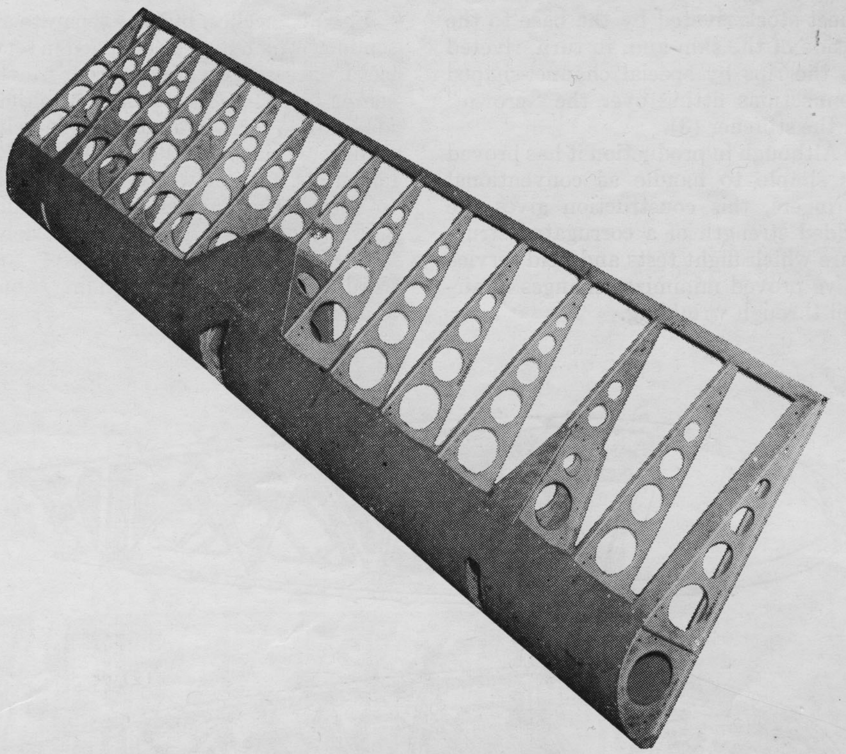


Fig. 9. Aileron structure. The nose portion has metal skin, and the entire assembly is fabric-covered. Only the right inboard aileron has a tab.

Curtiss C-46 Commando

The Commando wing, of full cantilever construction, is built in three sections (1): an untapered center section and two outer panels with detachable tips.

The center section is continuous through the fuselage, with three built-up spars taking landing and flight weights. The fore spar, running only through the center section, was provided to get the maximum moment of inertia and to provide a torque box within a limited area. Landing gear fittings and engine nacelles attach to this spar.

All three spars are stiffened shear webs with extruded flanges next to the skin. Center section ribs are truss type (2), built up of rolled and extruded sections. Stressed skin of 24ST alclad is used throughout the wing, with an interesting design for additional rigidity provided by spanwise hat-shaped stiffeners of rolled 24ST alclad

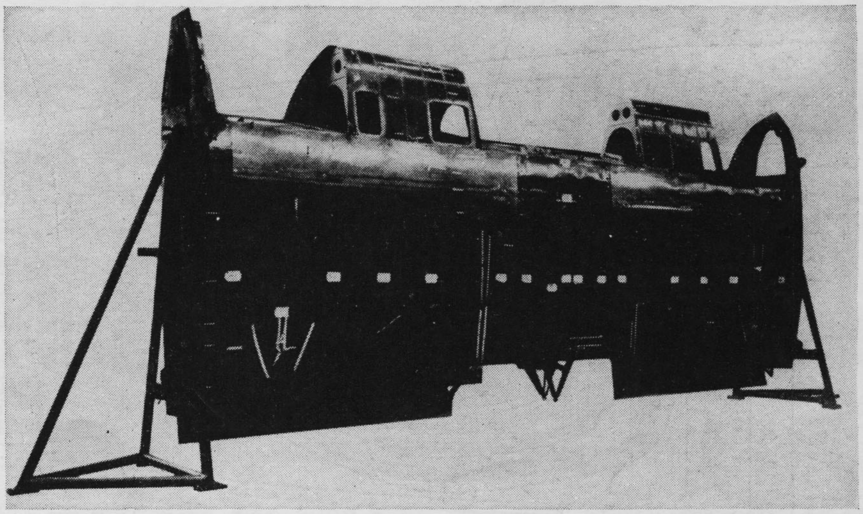


Fig. 1. The full cantilever wing is built in three sections: an untapered center section and two outer panels with detachable tips. The center section (shown) runs through the fuselage just below the cabin floor. Three spars are utilized in this section, with engine nacelles and landing gear fittings attaching to the fore spar. Note the aileron control hinge fitting at lower center, flanked by inboard flap hinges.

sheet stock riveted by the base to the inside of the skin and, in turn, riveted to the ribs by special channel-shaped connections fitting over the "crown" of the stiffener (3).

Although in production it has proved as simple to handle as conventional stringers, this construction gives the added strength of a corrugated structure which flight tests and field service have proved minimizes changes in airfoil through wrinkling.

Engine nacelles, built as separate assemblies which may be changed in service if necessary, are riveted to the center panel. The nacelles, of aluminum alloy, are semimonocoque with transverse rings and stringers and five longerons, four of which carry fittings to attach the engines and fire walls. The fire walls are of the "sandwich" type—light-gauge stainless-steel forward, asbestos sheet for "filling," and aluminum alloy aft.

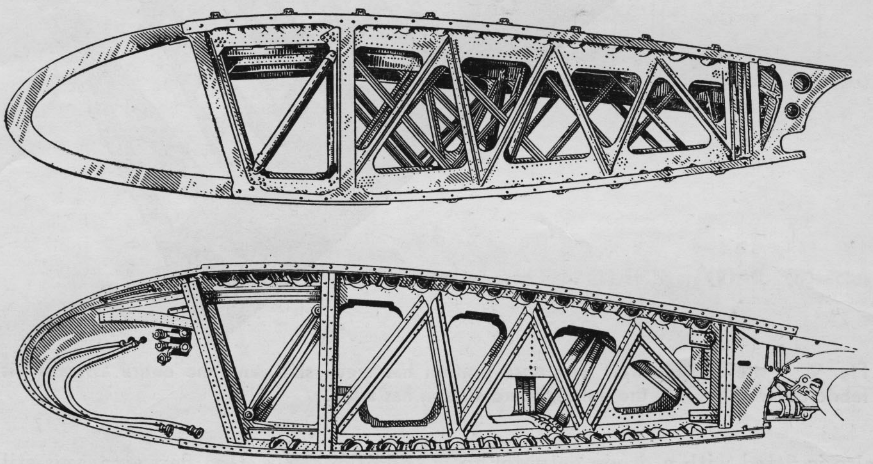


Fig. 2. The development of the truss-type center section ribs from prototype CW-20 to the later production model C-46 is shown here in detail sketches, revealing C-46 ribs (bottom) as being comprised largely of rolled sections and extrusions to give maximum strength and minimum weight. Engine nacelle-landing gear compression member, seen between the fore and main spars, has also been changed from angular to round shape.

The engine mounts are conventional chrome-moly steel tubing. Fittings are welded to each engine mount ring at six points for attachment, and cushion-type engine support fittings are furnished with the engine. All welded subassembly parts are normalized.

Removable outer wing panels are attached to the center section just outboard of the engine nacelles by special high-strength bolts encircling the wing through a splice plate. The first four ribs of the outer panel are web type, with large irregular hexagonal cutouts to allow space for three fuel tanks (4). The fifth rib is solid aluminum alloy with extruded flanges, and from there on out to the tip, ribs are web-truss type. These ribs are formed in one hydropress operation, the cutouts being blanked and a bead for added stiffness being put in during the one press stroke. Detachable wing tips are attached by machine screws.

Four Curtiss hydraulically operated flaps, which, in first operation stage, move 3 in. directly to the rear to create a slot and then, by means of a pantograph linkage, pivot downward to a maximum of 35 deg for landing or any intermediate angle to shorten take-off run, contribute vitally to the Commando's performance.

There are two pairs of flaps: the inboard (5) extending from the fuselage to the outer panel splice and having a span of 139.25 in., and an area of

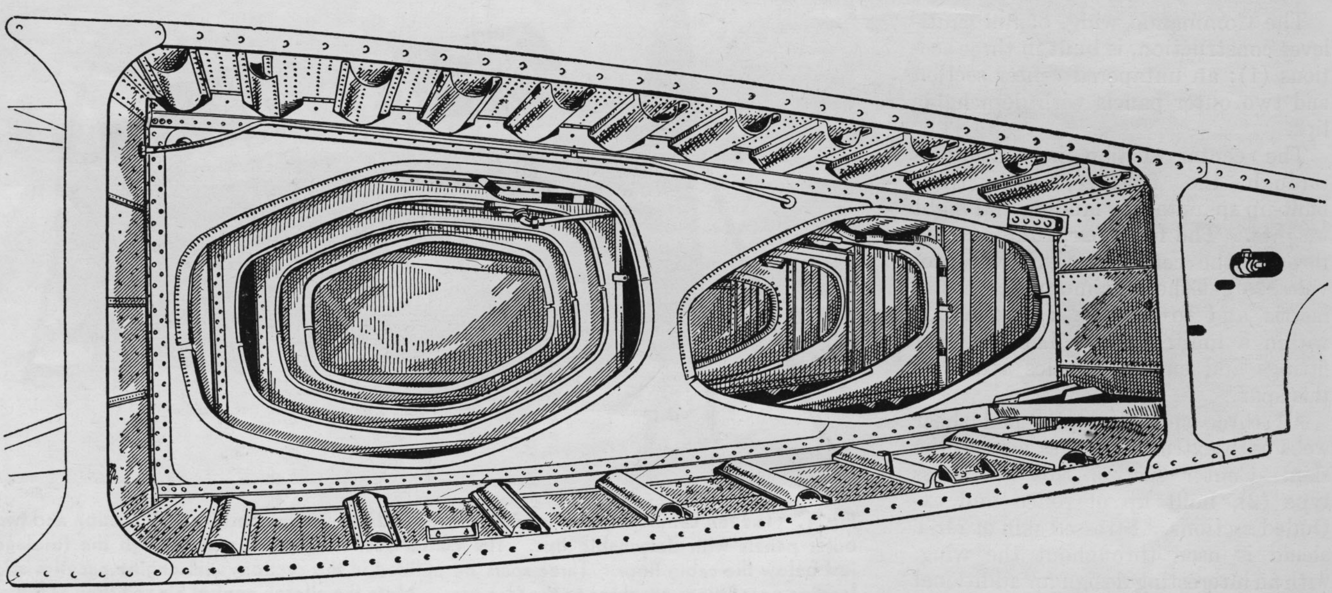


Fig. 3. A cross section of a wing between spars gives details of the corrugated effect created by spanwise hat-shaped stiffeners used in place of conventional stringers. Flight tests and field service have shown this design to be very efficient in eliminating airfoil changes due to wrinkling.

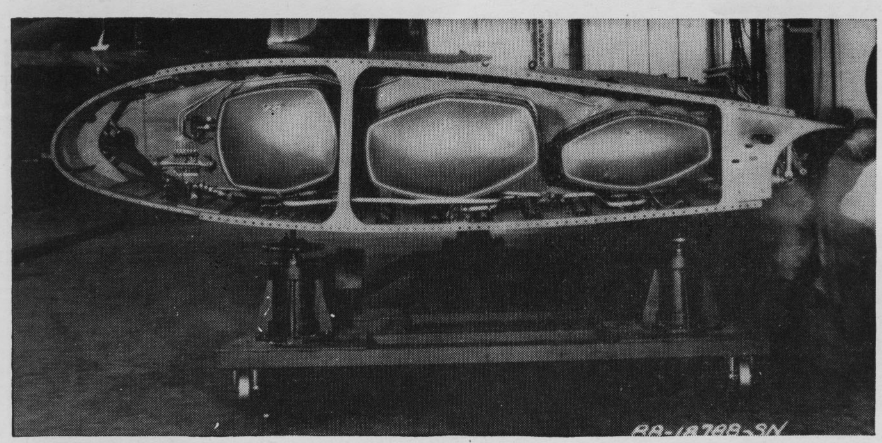


Fig. 4. Profile of the inboard end of an outer wing panel showing the installation of three standard aluminum alloy fuel tanks, which are supported in the first four cutout ribs so arranged that flexing or bending cannot be transmitted to the tanks. The fore tank carries 242 gal; mid-tank, 283 gal; aft tank, 175 gal.

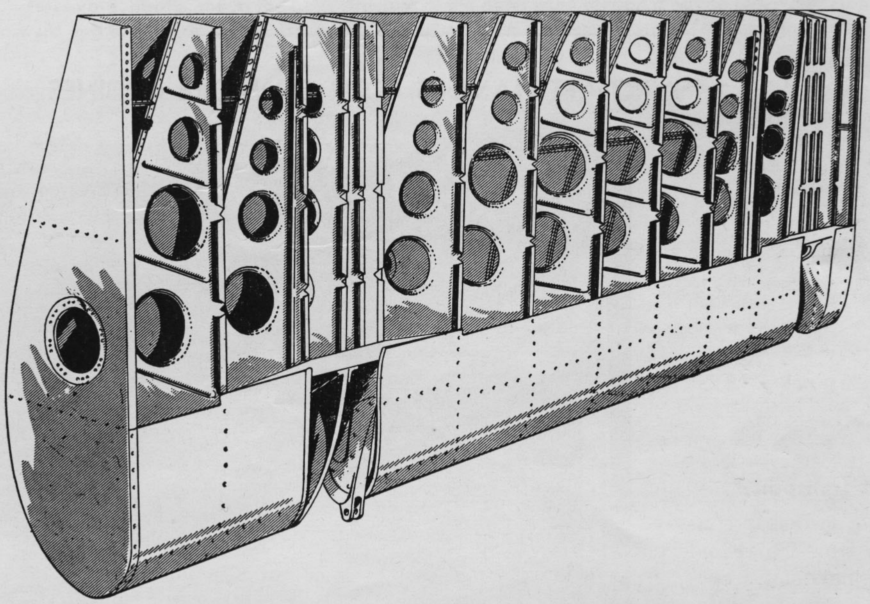


Fig. 5. The inboard flap is of conventional design, embracing a main spar, stamped ribs, and metal covering. Inboard flaps extend from the fuselage to the outer panel splice; outboard from there to the ailerons. The respective spans are 139.25 and 172 in.

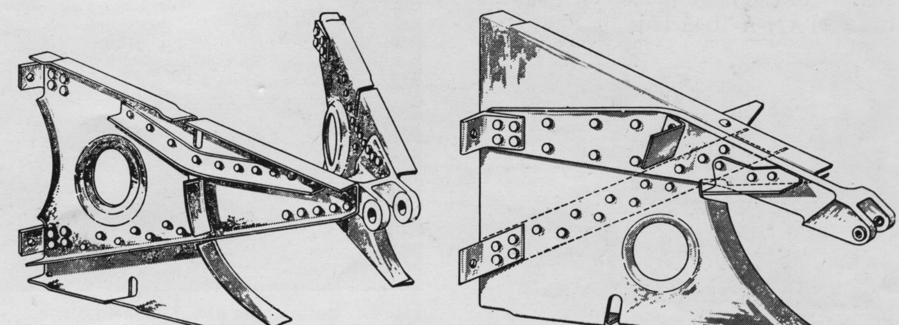


Fig. 6. Aileron hinge ribs, showing the construction types used on two of six for each aileron.

46.92 sq ft, and the outboard flaps extending to the ailerons with a span of 172 in. and an area of 51.79 sq ft each. The flaps themselves are conventional structures, having a main spar and stamped ribs, metal-covered.

The ailerons are the only fabric-covered surfaces on the C-46 (7). The leading edge is a torsion box, and a single spar of flanged sheet metal with lightening holes is used. Stamped ribs are 24ST. Each aileron—with an area of 39.57 sq ft—is attached at hinge ribs (6) by six ball-bearing hinges and has an arc of 35 deg above horizontal to 20 deg below. Static and dynamic balance is obtained by a lead weight along the L.E., forward of the hinge line. Each aileron has a trapezoidal-shaped trim tab along the inboard trailing edge, span being 58.5 in., maximum chord 10.30 in., and area 3.97 sq. ft.

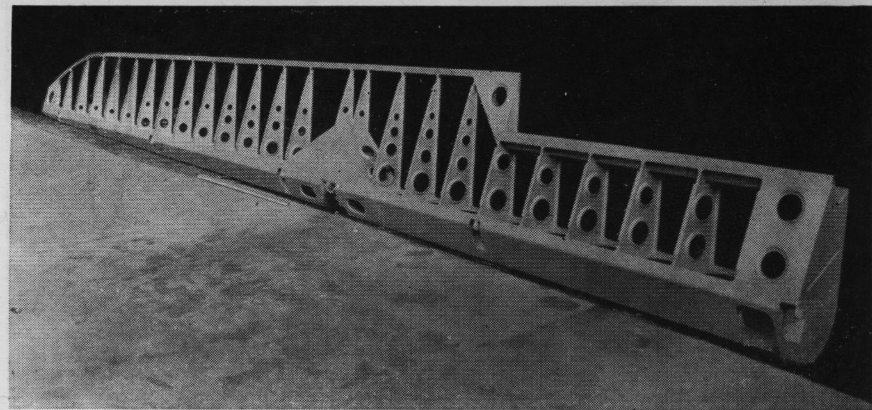


Fig. 7. The only fabric-covered surfaces on the Commando are ailerons, which have metal spar and 24ST stamped ribs. Static and dynamic balance is obtained by weight along the L.E. ahead of the hinge line. Attachment is by six ball-bearing hinges, and ailerons swing in an arc ranging from 35 deg above horizontal to 20 deg below.

PART 3. AIRCRAFT HAVING FOUR OR MORE ENGINES

Avro C.102 Jet Transport

The C.102 wing is of two-spar construction employing truss-type and solid ribs with lightening holes. Sections between the spars serve as integral fuel tanks. All riveting is flush and leakproof.

The skin and stiffeners are made up as complete subassembly prior to assembly of the main plane (1). Skin is of 75 STAN-A-10 alclad.

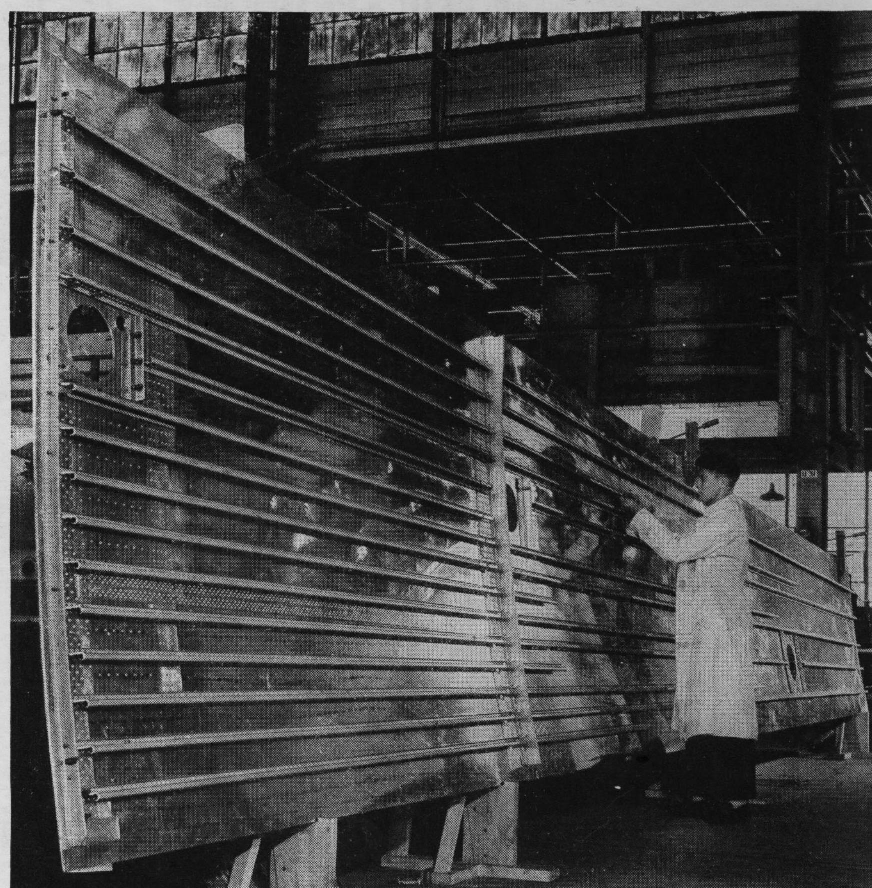


Fig. 1. Bottom skin of C.102 main plane. The skin and stiffeners are made up as a complete subassembly prior to assembly of the main plane. The stringers are J section, and the skin of 75ST alclad is flush-riveted and leakproof.

Lockheed Constitution (XR60-1)

The XR60-1 wing is of all-metal two-spar construction (1). A rectangular opening in the rib section is provided so that inspection and minor repairs may be quickly carried out.

The flaps are built of ten identical segments—five to each wing structure (2). The sections are interchangeable, each having a span of 118 in. and 67-in. chord.

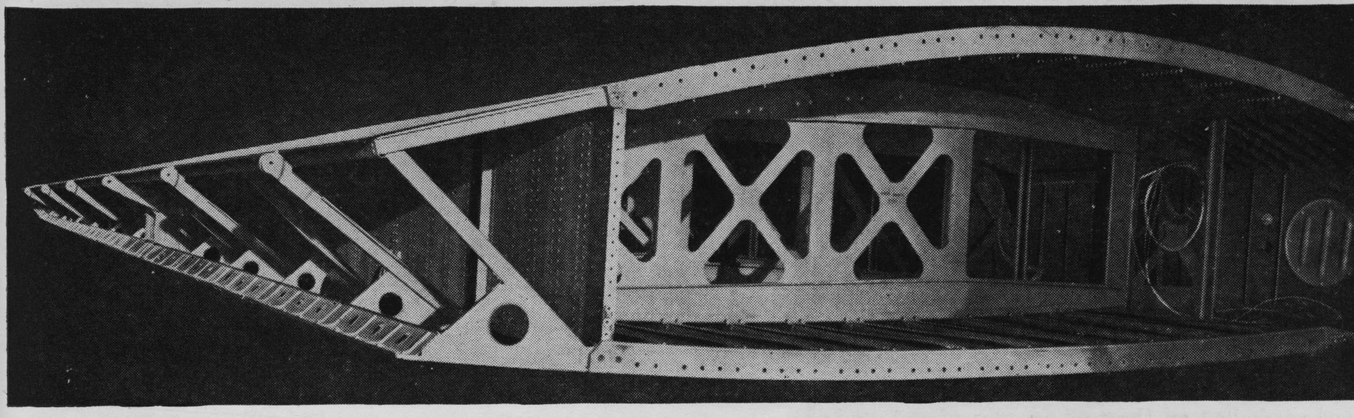


Fig. 1. Outer wing panel. Assembly, above, shows the basic structure of the outer wing section ready to receive ailerons. The rib section has a rectangular opening at tne forward end to provide tunnel space, making the wing inner areas accessible for quick inspection and repair.

Fig. 2. Segmented flaps. Ten identical segments comprise the mammoth flap system on the Lockheed Constitution, five units joined uniformly on each wing structure.

Northrop B-35 and YB-49

The wing of the B-35 and YB-49 is of orthodox construction with two spars, ribs, and hat-section stringers, and stressed skin. The full cantilever wing is divided into the following sections: crew nacelle, which forms the wing root, two center panels and two outer panels. With the exception of the wing tips, the wing is constructed in one piece.

In the YB-49 vertical fins or "air separators" add to the jet-powered bomber's stability.

The landing flaps (1) are hinged to the rear wing spar, extending from each side of the crew nacelle to the outboard propeller housings. The flaps weigh approximately 225 lb each and are smaller than the elevons.

The elevons are fabric-covered surfaces installed on the trailing edge of the wing, extending from the landing flaps to the rudder-trim flap combinations at the tips (2). Each elevon weighs about 290 lb.

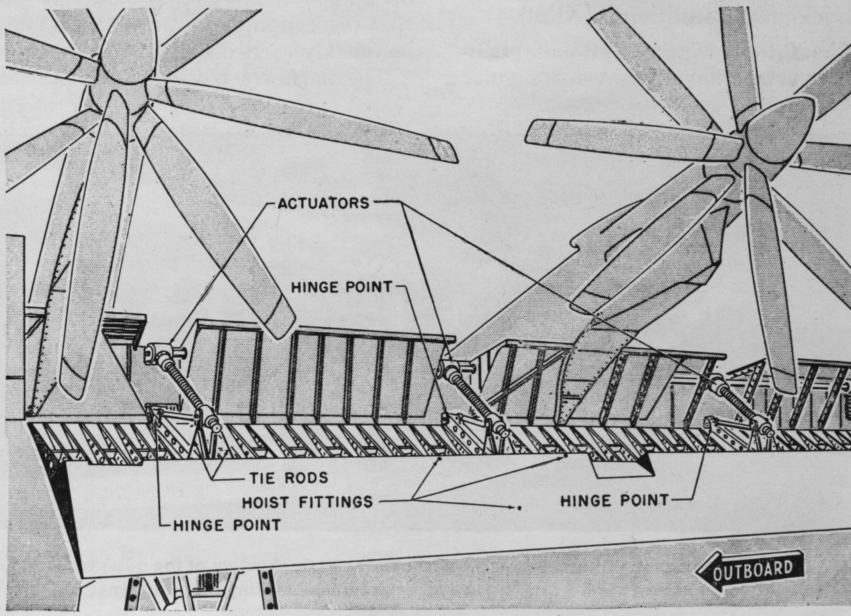


Fig. 1. B-35 landing flap installed.

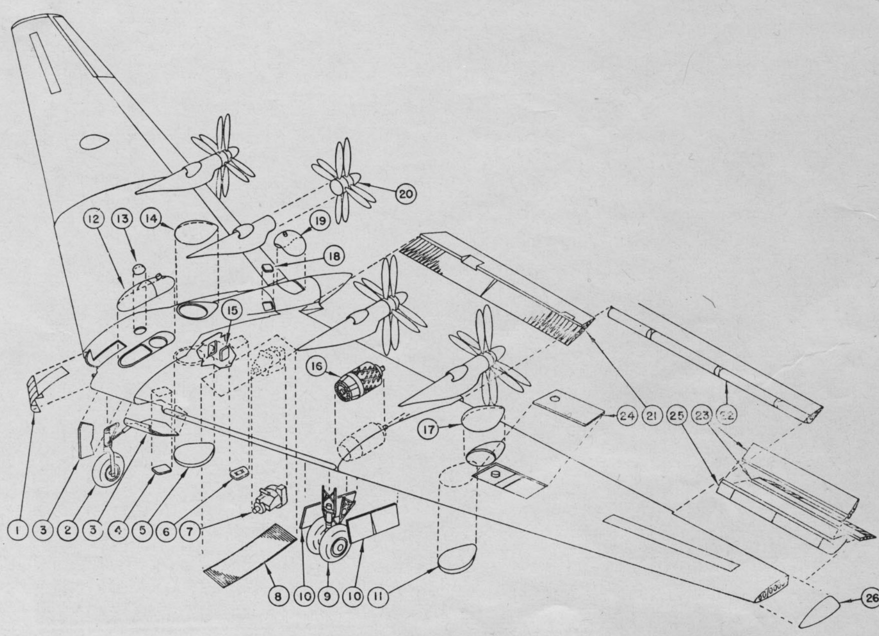


Fig. 2. Major assembly breakdown showing arrangement of flaps, elevons, rudders, and trim flaps on the wing. Other features are: (1) copilot's enclosure; (2) nose landing gear; (3) nose landing gear doors; (4) lower escape hatch; (5) nacelle turret-bottom fairing; (6) main entrance hatch; (7) auxiliary power plant; (8) bomb-bay roller door; (9) main landing gear; (10) main gear doors; (11) wing turret-bottom fairing; (12) pilot's enclosure; (13) astrodome; (14) nacelle turret-top fairing; (15) bomb-bay escape hatch; (16) engine (in the jet-powered YB-49; "air separators" replace propeller shaft nacelles with four TG-180 engines installed in between); (17) wing turret-top fairing; (18) upper escape hatch; (19) sighting station, upper enclosure; (20) propellers, including gearbox; (21) landing flap; (22) elevon; (23) rudder; (24) fuel tank door; (25) trim flaps; (26) wing tips.

Canadian North Star

The full cantilever all-metal wing of the North Star is composed of a center section and inner wing panels constructed as a unit with permanently attached nacelles, removable outer wing panels bolted to the inner panels, and removable wing tips.

An aileron is attached to each outer wing panel, the right aileron incorporating a trim tab. The leading edges of the wings are equipped with deicer boots. Two hydraulically operated flaps are designed to move aft and down on linkages attached to the inner wing panels.

Two integral fuel tanks are incorporated in the structure of each inner wing panel, and one integral tank is incorporated in the outer panel. In addition, a collapsible tank is incorporated in each stub wing.

The center wing section passes through the fuselage and is permanently attached to it; a small stub extends on each side of the fuselage.

Three spars extend the entire span of the inner panels, terminating at the outer wing attaching points. The outer panels have a full-length spar which is a continuation of the center spar of the inner panel, and a false spar which is a continuation of the front spar of the inner wing. The outer wing panel attaches to the inner wing by studs, internal wrenching bolts, and internal wrenching nuts (1). Each outer panel weighs about 770 lb.

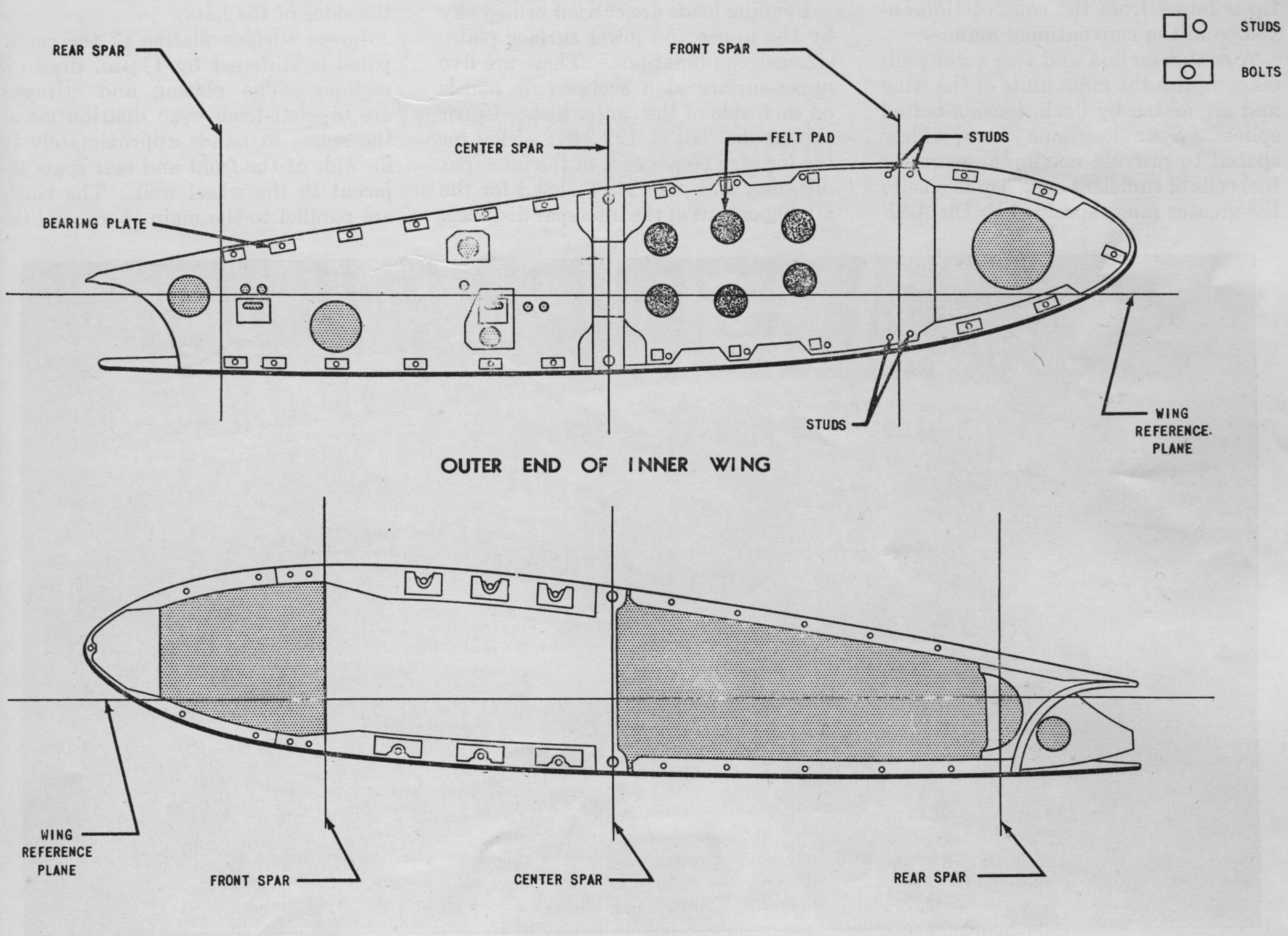
Inasmuch as the spars, bulkheads, and skin are used as tanks, the structure in the tank areas is designed to be leakproof. A minimum of three rows of rivets is used wherever possible. In addition, a seam-sealing compound is applied as a filler on all seams leading to the tank interior. The rib structure in the tank area serves to dampen the surging fuel. Removable stressed access doors, located on the lower surface of the wing, provide access to the tank interiors.

The structure of each inner panel is modified between stations 60 and 130 to accommodate an additional bladder tank.

The wing tips are bolted to the outer panels and are similar in construction to the wing panels. The tips weigh about 25 lb each.

The ailerons are fabric-covered aluminum alloy components consisting of a spar extending the entire span of the aileron, ribs spaced equally along the spar, and a formed aluminum alloy trailing edge. The structure forward of the spar is covered with aluminum alloy sheet; lead weights are bolted to the sheet, balancing the aileron on its hinges.

The flaps are of all-metal aluminum alloy single-spar construction. The



INNER END OF OUTER WING

Fig. 1. Outer wing to inner wing joint.

spar consists of a continuous shear web with lightening holes, reinforced by stiffener angles riveted to the web, and upper and lower extruded cap angles.

The nose section and trailing section ribs of the flap are provided with lightening holes and riveted to the spar web. The entire frame is strengthened with stringers running lengthwise through the flap nose section. The skin is aluminum alloy.

Consolidated Vultee B-24

The wing design of the B-24 was based on a geometrically similar airfoil used with considerable success on Consolidated Vultee model 31 flying boat. Ease of production was one of the main considerations in selecting this design.

The wing envelope is established, connecting corresponding percentage ordinates of the construction root and construction tip sections. The construction tip and root sections are normal to a chord plane. Each left and right chord plane is set at an angle of 3°26′ to the horizontal, and the chord section on the plane of symmetry is established by intersections of the percentage point connecting lines. The tip is faired from the construction envelope in the conventional manner.

A center section and two outer panels comprise the main units of the wing and are mated by flush, tension-bolted splices. Spar locations were widely spaced to provide maximum room for fuel cells of sufficient capacity to ensure the greater range specified by the AAF (1), and also to provide clearance for main landing gear wheels.

The center section (2) has a span of 55 ft, and its structure includes two auxiliary spars of plate girder type, built up of heavy, rolled angles and flat sheet riveted to two of the main wing bulkheads to support the landing gear. Both main and auxiliary spars are Wagner type with Z-section vertical stiffeners spaced 4 to 6 in. apart, and with rolled angle flanges. To eliminate joggles, the flanges are placed back to back on the web against the face of the paired angles. Stiffeners are placed on the web surface opposite the flanges, so that the components can be fitted easily together without appreciable loss of structural efficiency.

Bending loads are carried principally by the upper and lower surface plate-stringer combinations. There are five upper-surface skin sections or panels on each side of the center line. Upper skin at the root is .125 24ST alclad for the forward 60 per cent of the interspar distance, and .091 24ST alclad for the aft 40 per cent of the interspar distance.

These skins extend spanwise 147 in., to the end of the main fuel cell region. The remaining skins on the upper surface of the center section are divided into three strips: forward strip is .114, center strip .102, and the aft strip .091 24ST alclad. Gauge reductions are made to save weight when strength requirements are reduced.

Rolled hat-section stringers of approximately similar gauges are used for skin stiffening. Skin and hat splices occur at the bulkheads 147 in. from the center line (4). Forged, flanged strap fittings and splice plates connect both hat sections and skins. At the outer panel-to-center section splice the hat sections are connected to an inverted flange splice by U forgings riveted to the sides of the hats.

Lower surface plating of the center panel is stiffened by 1½-in. drawn Z sections. The plating and stringers are tapered from even distribution at the splice to bands approximately 10 in. wide at the front and rear spars adjacent to the wheel well. The bands are parallel to the main spars, and the

Fig. 1. Wing structure at the space for fuel cells. Dot fasteners on the bulkheads and ribs are used to attach canvas covers to protect the cells from abrasion.

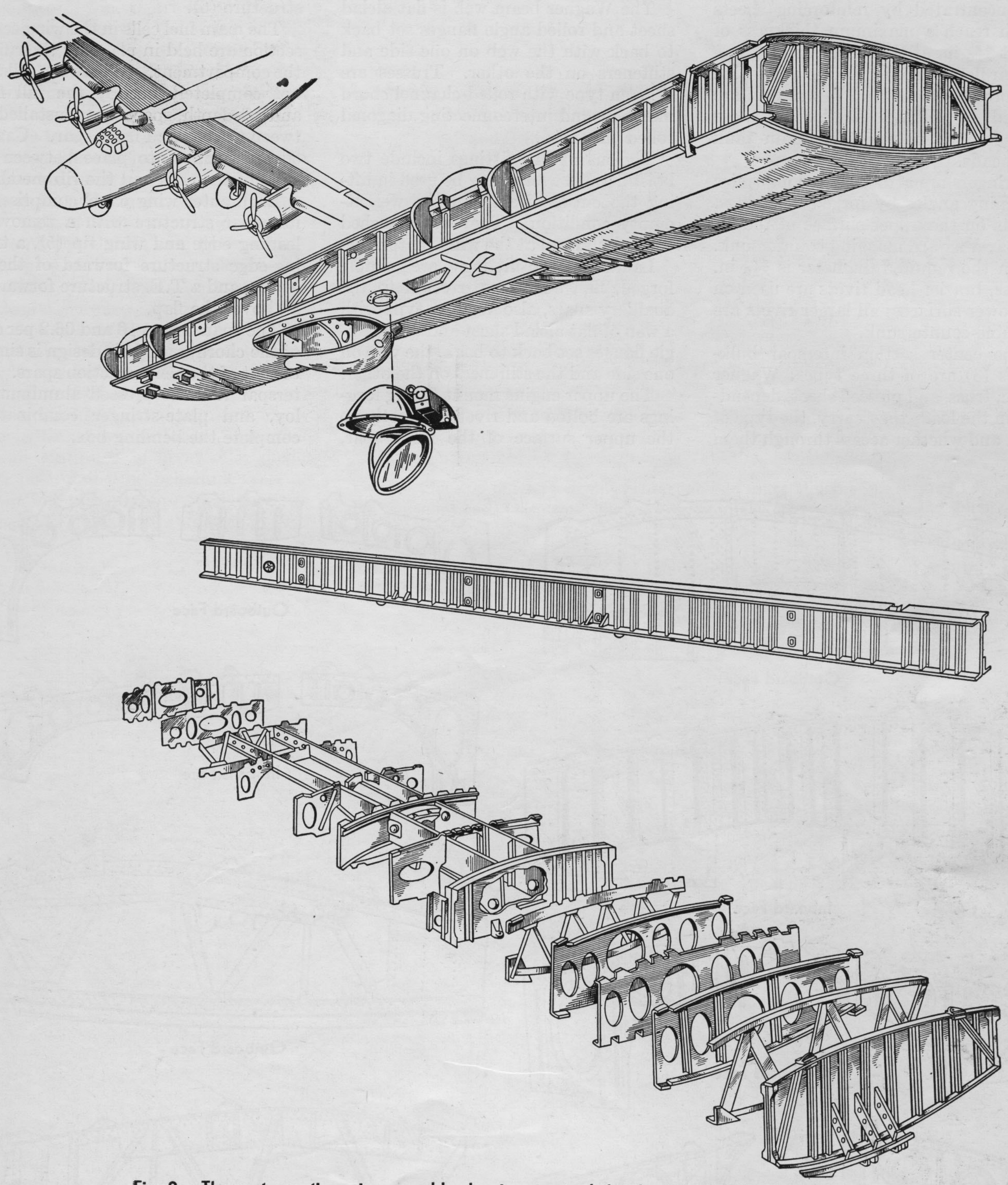


Fig. 2. The center section wing assembly showing structural details of the bulkheads and spars.

plating becomes continuous at the outboard end of the fuel tank. Material is concentrated by reinforcing sheets which reach a maximum thickness of about $\frac{9}{16}$ in. at the wheel well.

Spar flanges are joggled to accept the reinforcing sheets, and Z stringers are spliced by fittings similar to those used for the hats at the main tank bulkheads.

Stringers are attached to wing splice attaching angles by forged T fittings. Rivets on the upper surface of the interspar area are machine-countersunk. When the required diameter is $\frac{3}{16}$ in. or less, brazier-head rivets are used on the lower surfaces; all larger rivets are machine-countersunk.

The center section interspar bulkheads (3) are of three types: Wagner beam, truss, and pressed sheet, depending on the loads they carry, the type of load, and whether access through them is required. There are 27 of them, 13 on each side and one at the center.

The Wagner beam web is flat alclad sheet and rolled angle flanges set back to back with the web on one side and stiffeners on the other. Trusses are Warren type with rolled-channel chord members and interconnecting diagonal rolled channels.

The main wing fittings include two hoist fittings which may be used in lifting the entire aircraft in the weight-empty condition. They are attached to the bulkhead at the wing center line.

Landing gear fittings are simple forged, flanged bosses, riveted to the auxiliary spars, also Wagner type with a web of flat alclad sheet and rolled angle flanges set back to back, the web on one side and the stiffeners on the other.

The upper engine mount fitting forgings are bolted and riveted directly to the upper surface of the front spar, while the lower engine mount fittings are carried on a welded tubular substructure (6).

The main fuel cells in the wing center section are held in place by their fit to the compartment. Where the cell does not completely occupy the full fore-and-aft depth, spacers are installed between the cell and front spar. Canvas curtains snap into place between the sides of the cells and the rib members.

Each outer wing panel comprises an interspar structure with a removable leading edge and wing tip (5), a trailing-edge structure forward of the ailerons, and a T.E. structure forward of and over the flap.

The spars are at 10 and 66.2 per cent of the chord, and their design is similar to that of the center section spars. Interspar ribs are pressed aluminum alloy, and plate-stringer combinations complete the bending box.

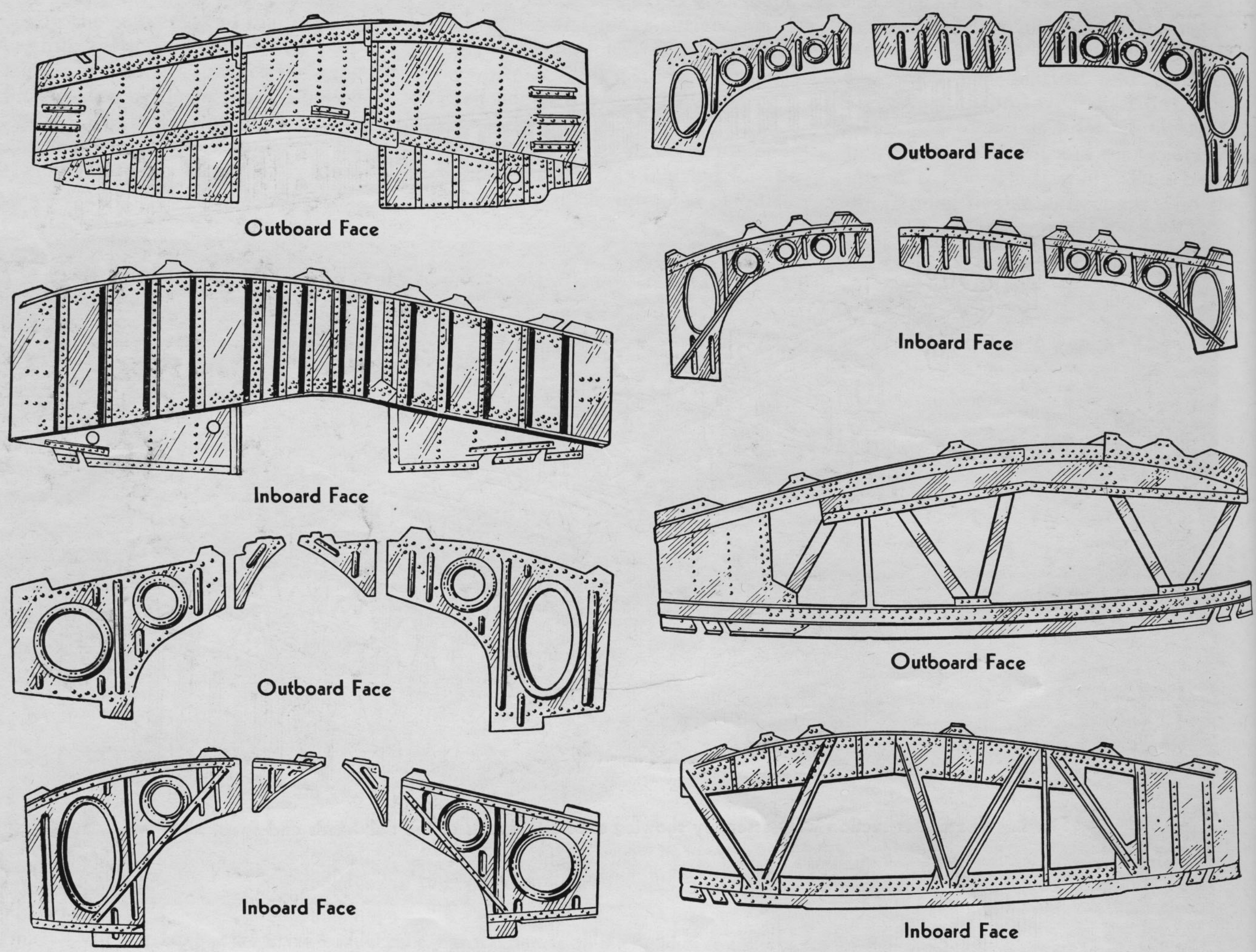


Fig. 3. Typical wing center panel bulkheads.

The upper surface employs hat sections at the inboard end, and these splice into 1½-in. Z stringers which in turn splice down to 1-in. stringers and terminate at the base of the wing tip.

The lower surface plate-stringer combination is similar, except for the fact that hat sections are not used, 1½- and 1-in. Z's being used for stiffeners.

During assembly operations, the wing skins were applied to the upper surface first, the front and rear strips were then attached to the lower surface, and the closure completed by attaching a center strip provided with handholes. Later assembly procedures made it possible to attach plate-stringer surfaces as units.

The ailerons (7) are of typical torque-box pressed-rib construction, fabric-covered. A two-horn gearbox control system was used originally in connection with these surfaces, but this was discontinued in favor of a single horn push-pull tube bellcrank system. Trimming tabs are provided on both ailerons of the latest Liberators.

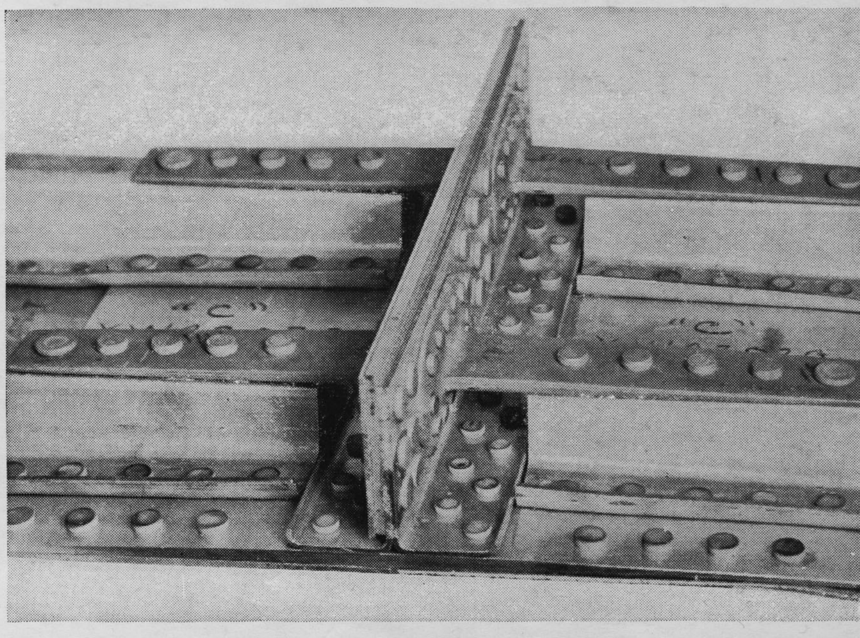


Fig. 4. Close-up of a typical wing hat-section skin splice at bulkheads located 147 in. from the center line and at the center line. Note the forged flange strap fittings and splice plate.

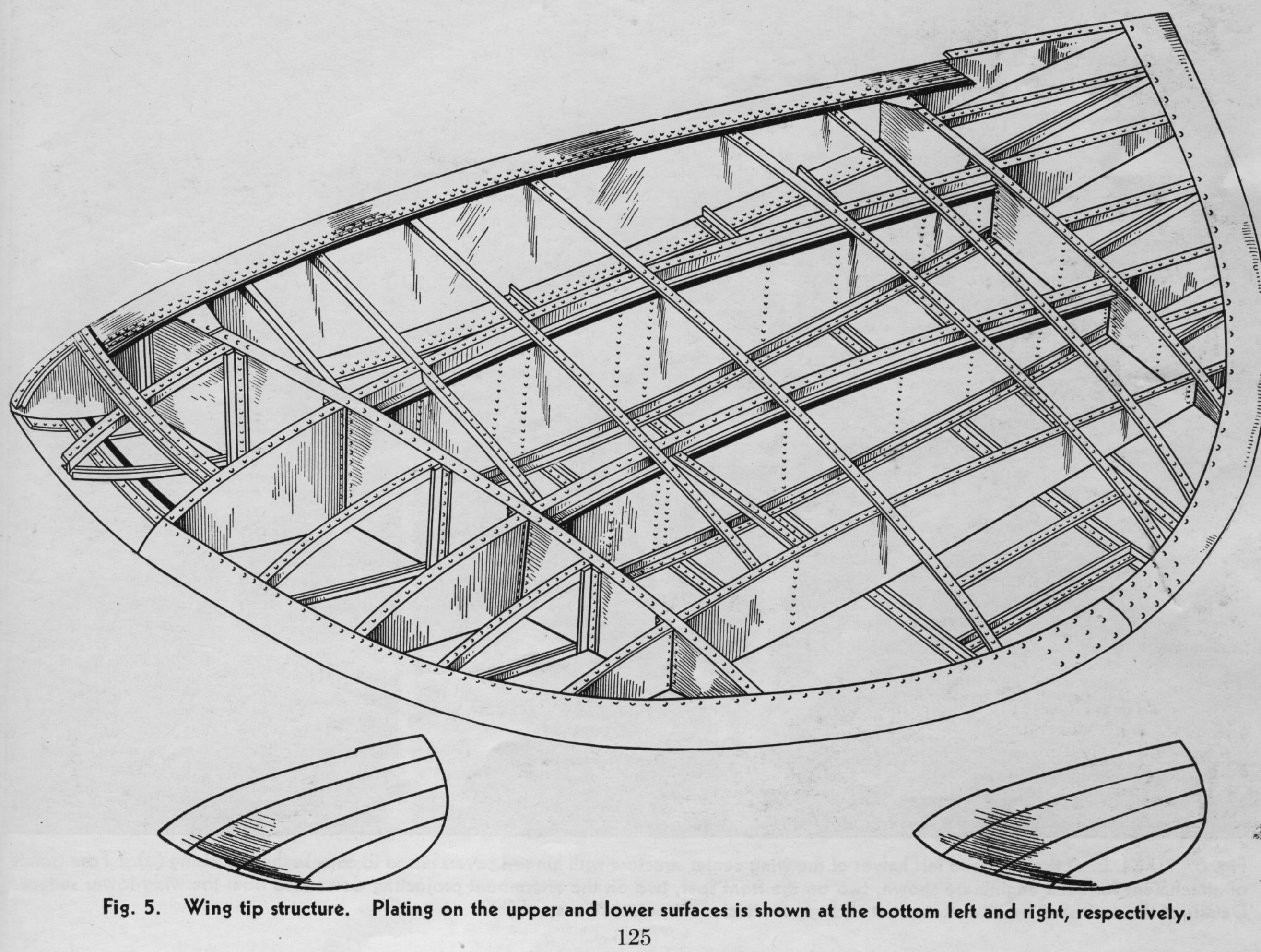
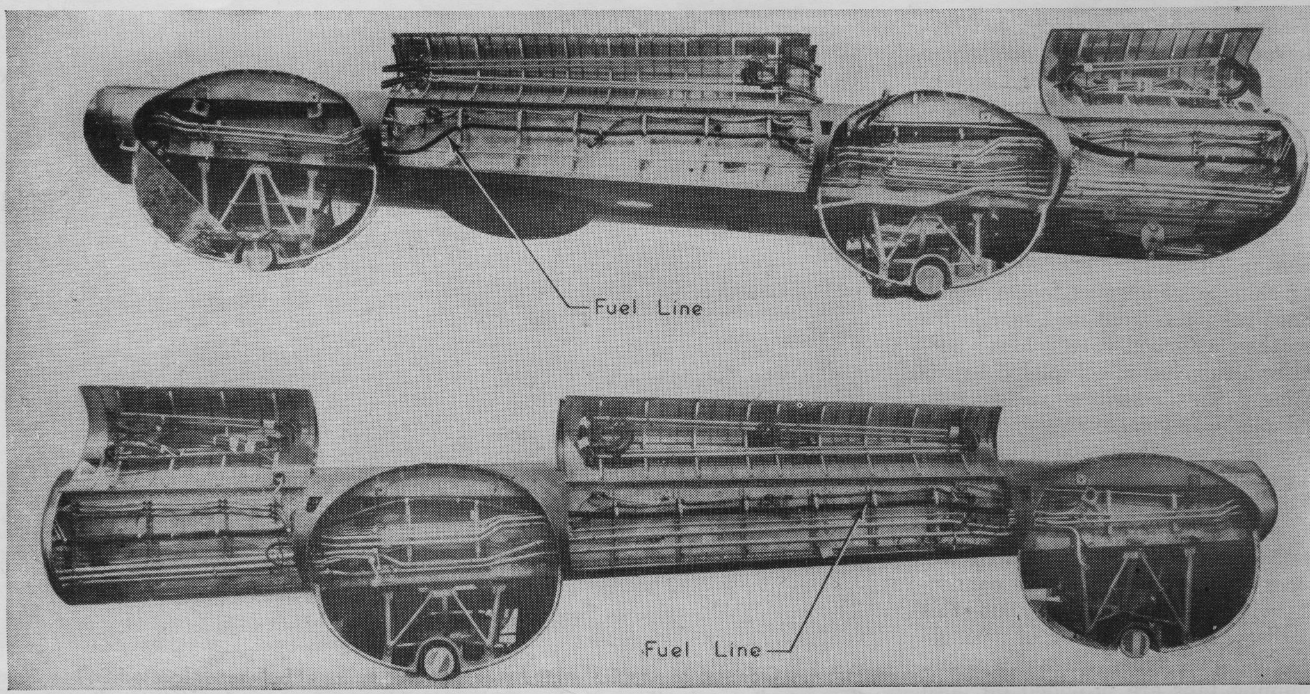


Fig. 5. Wing tip structure. Plating on the upper and lower surfaces is shown at the bottom left and right, respectively.



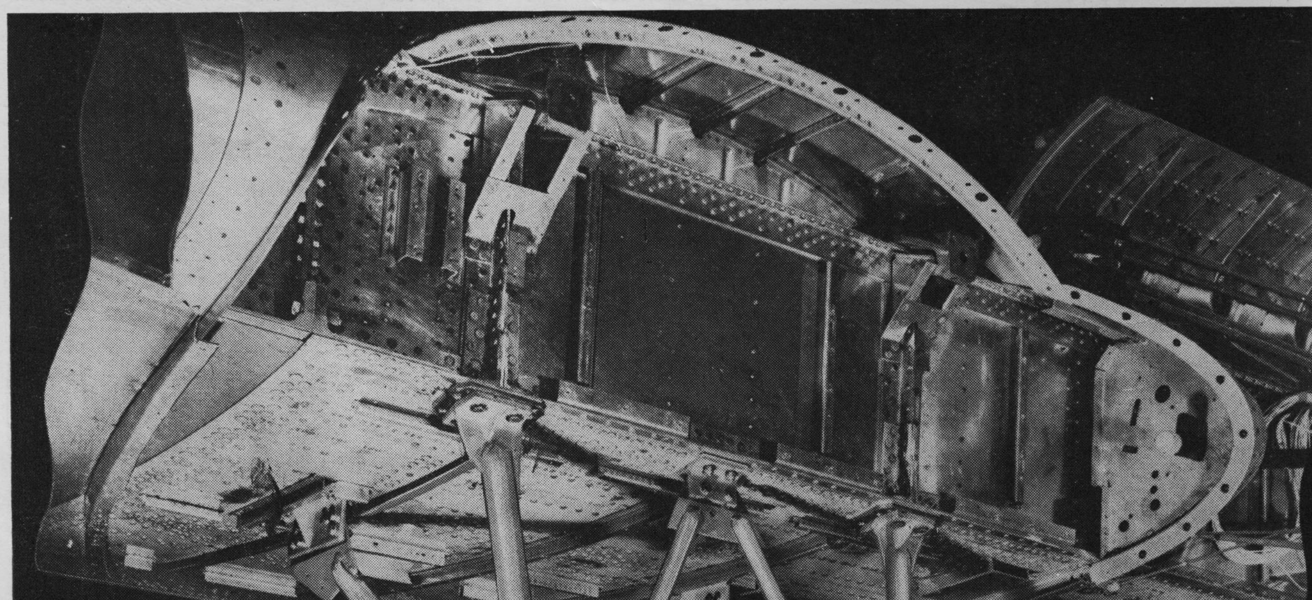


Fig. 6. The L.E. of the right and left halves of the wing center structure with hinged covers raised to expose the plumbing (*a*). Four points of attachment for each engine are shown, two on the front spar, two on the aftermount projecting downward from the wing lower surface. Details of the outboard nacelle aftermount and upper attachment point are seen at (*b*).

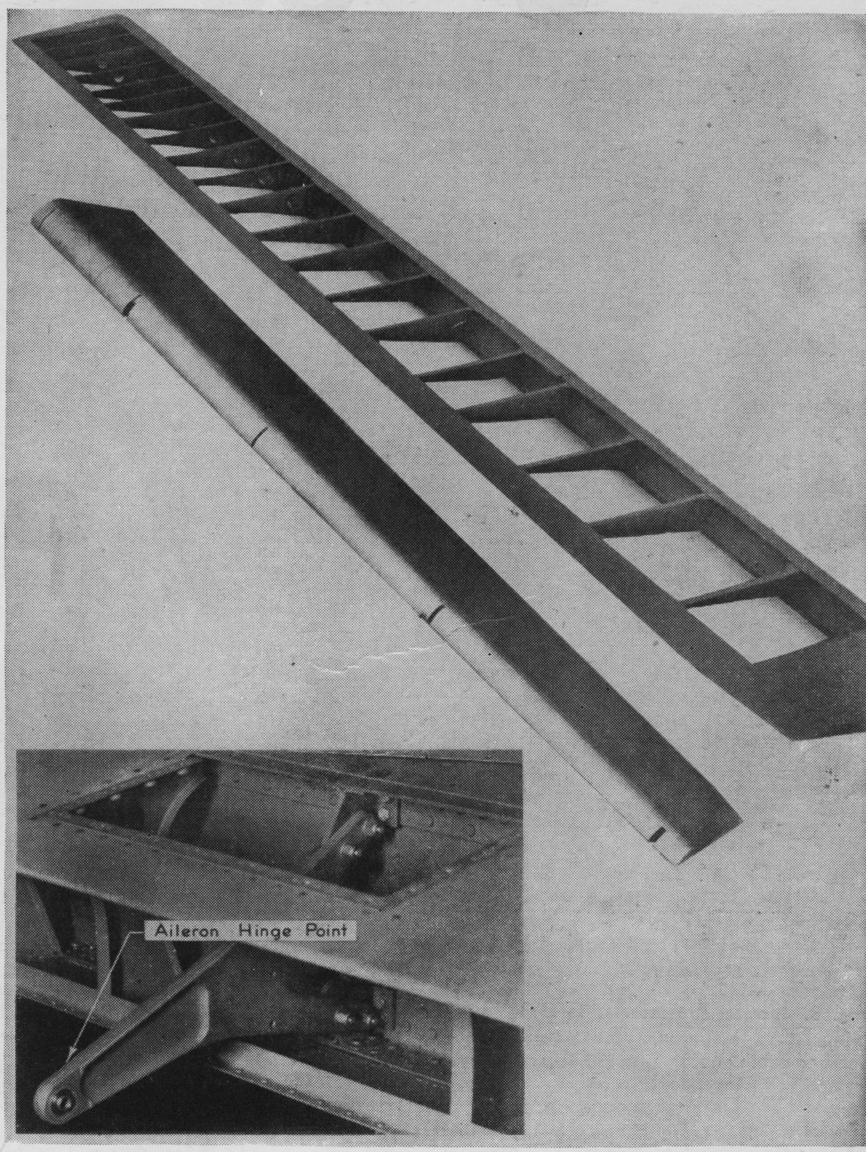


Fig. 7. Seen here are the structural features of an aileron. The assembly has an alclad sheet L.E. and is hinged to the wing outer panel at five points. The inset shows hinge attachment details.

In the B-24 wing, most rolled sections are stretched approximately 3½ per cent; and, since few extrusions are used, Convair has been able to control section output simply by using sheet stock. Although they are not so accurate dimensionally as extrusions, little trouble has been experienced in constructing the wings because of the flexibility of the fundamental design.

The Fowler flaps (8) have an area of approximately 144 sq ft and a movement downward of 40 deg. The individual flap is supported by roller carriages, which engage five tracks, four of which are attached to the center section and the fifth to the outer panel. Tracks are I beams bolted to a tubular planar truss. Clevises at the forward ends of the tubular truss attach to lugs which protrude through the spar at the spar flanges and attach to bulkhead chord members.

The flap controls comprise a cable system actuated by a hydraulic cylinder energized by pressure from the main hydraulic system.

Design weights of the wing are: center section, 4,715 lb; outer panel, 1,178 lb; tips, 39 lb; ailerons, 157 lb; flaps, 252 lb. Total weight, 6,575 lb.

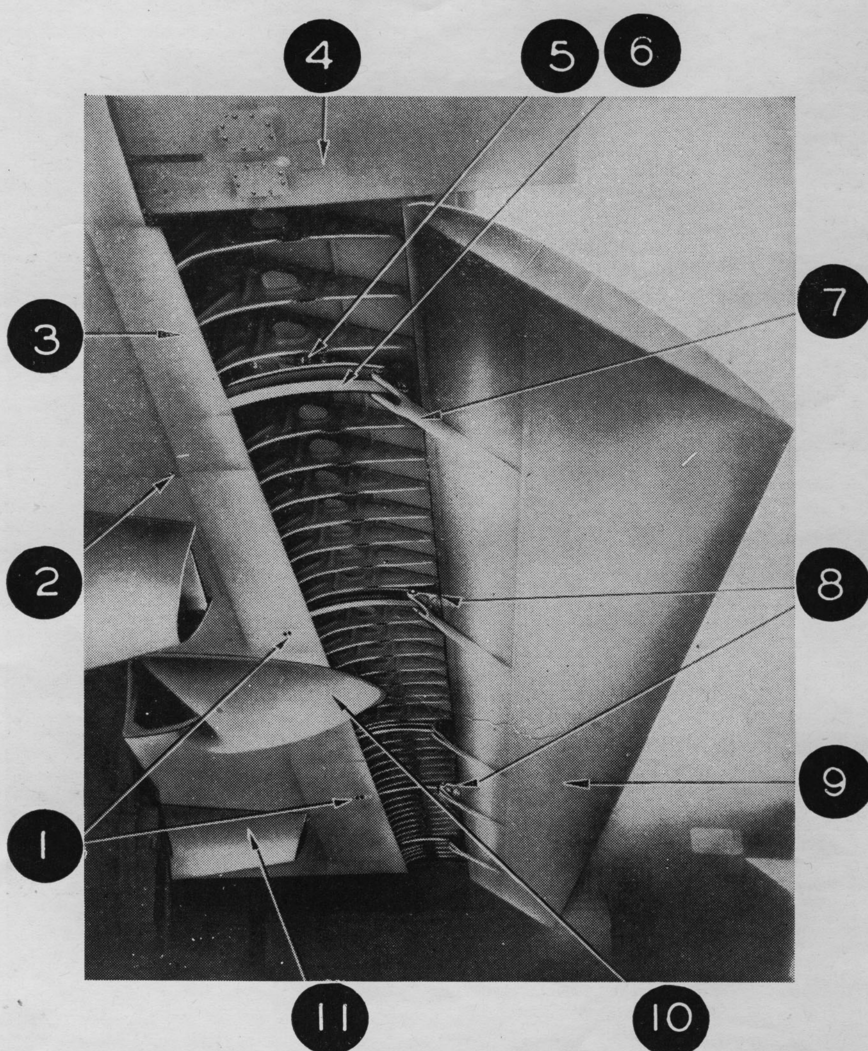


Fig. 8. Fowler-flap installation showing (1) up-stop inspection slots; (2) wing splice; (3) wing T.E.; (4) aileron; (5) flap-track support; (6) flap track; (7) flap carriage; (8) flap extending cable attachments; (9) flap; (10) wheel well fairing; (11) engine nacelle fairing.

Avro Lancaster

The wing center section of the Lancaster is built integral with the fuselage center section, the two main longerons of which attach directly to the wing center section spars.

Wing main spars (1) are U-section channels booms and flat plate webs. Skin attachment is to the sloping face of the boom, at the top or bottom according to the position of the boom on the spar. Spar construction details are given in (2) and (3).

The center section spar webs are of alclad plate, wider at the center where the web projects beyond the boom. Made in two sections, they are joined

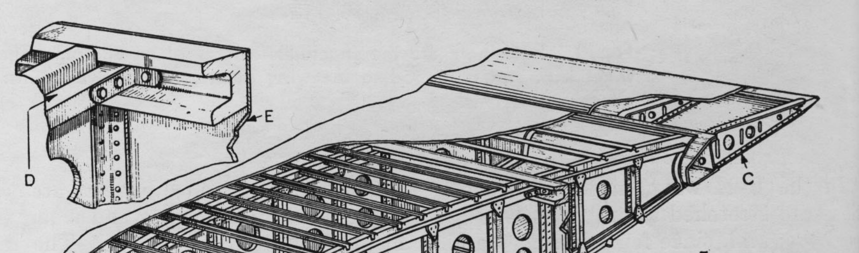


Fig. 1. Typical section through Lancaster wing, with front spar at *(A)*, rear spar at *(B)*, and aileron rib at *(C)*. The method of attaching rib *(D)* to spar *(E)* is shown in the detail sketch at the upper left; attachment of stringer *(F)* to rib *(G)* is shown in detail at the lower right.

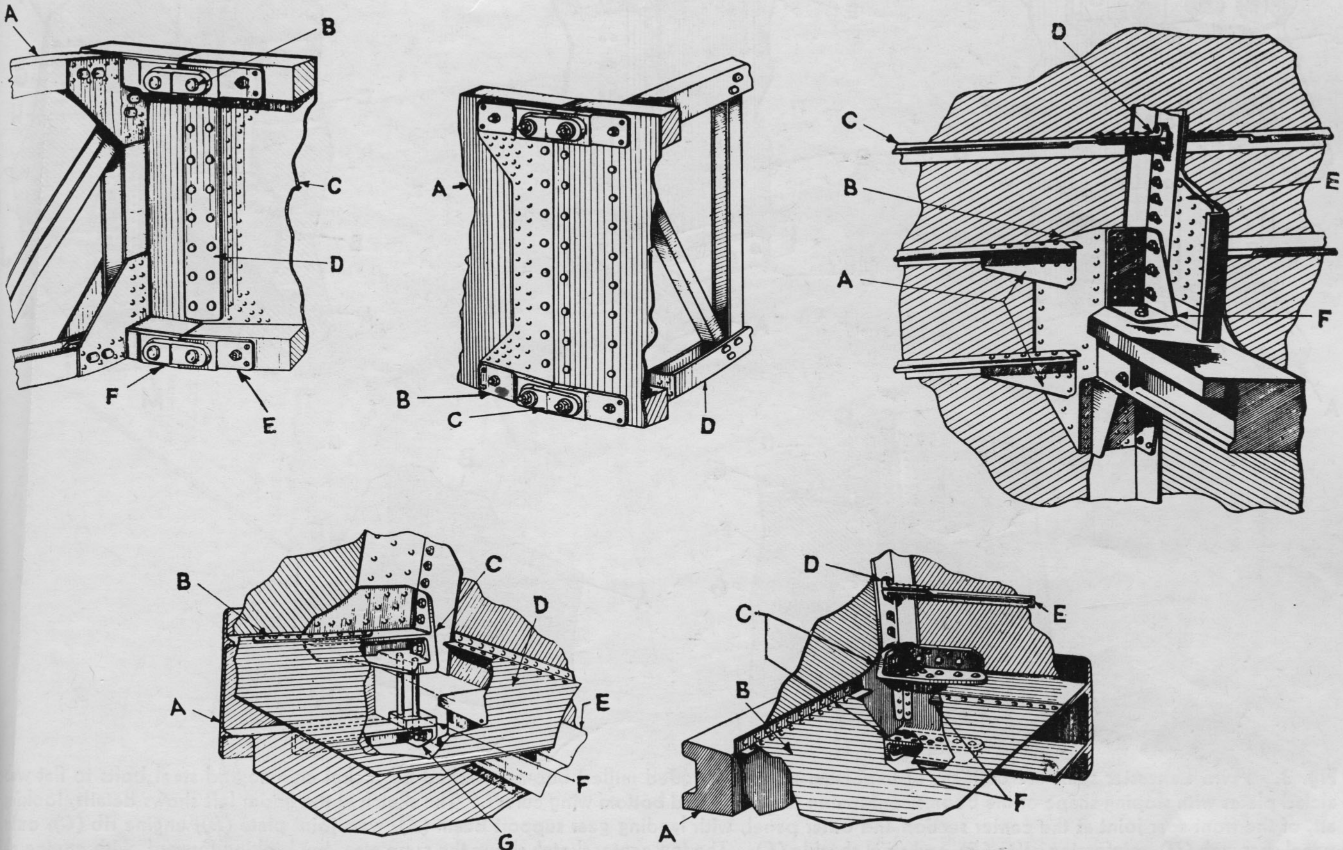


Fig. 2. The sketch at the upper left shows details of the Lancaster rear spar center section-to-outer panel joint, with engine rib (*A*), boom joint pin (*B*), outer panel spar web (*C*), web joint plate (*D*), reinforcing plate (*E*), and steel shackle (*F*). The top center sketch is of same area, looking forward, with outer panel web (*A*), reinforcing plate (*B*), shackle (*C*), and engine rib (*D*). The upper right sketch shows the connection of the rear spar upper boom to the fuselage, with stringer brackets (*A*), gusset plate (*B*), stringer (*C*), stringer attachment angle (*D*), web joint plate (*E*), and shoe bracket (*F*). The lower left sketch gives details of the rear spar bottom boom-to-fuselage joint, looking aft. The fuselage longeron is at (*A*), strap plate at (*B*), corner bracket at (*C*), floor top at (*D*), spar boom at (*E*), packing block at (*F*), and corner bracket at (*G*). The lower right sketch gives details looking forward, with spar boom (*A*), floor top (*B*), corner brackets (*C*), stringer attachment angle (*D*), and stringer (*E*). The longeron has been cut away at (*F*) for clarity.

by a gusset plate on the spar center line.

Outer panels have separate leading and trailing edges attached to front and rear spars and detachable wing tips.

Flush riveting, originally used, was superseded by mushroom-headed rivets because the skin buckling caused by semiskilled labor and countersinking was thus eliminated.

Fabric-covered ailerons are used, and the flaps are divided into center section and outer panel flaps.

The four welded-steel tubular engine mounts are attached to the front spar. Six fuel tanks are installed having a total capacity of 2,158 Imperial gal, equal to about 15,000 lb of fuel. The inboard tank (5) holds 585 gal; the outboard tank, 114 gal (4). Between them another tank holds 383 gal. Each tank has an electrically spot-welded structure made fueltight.

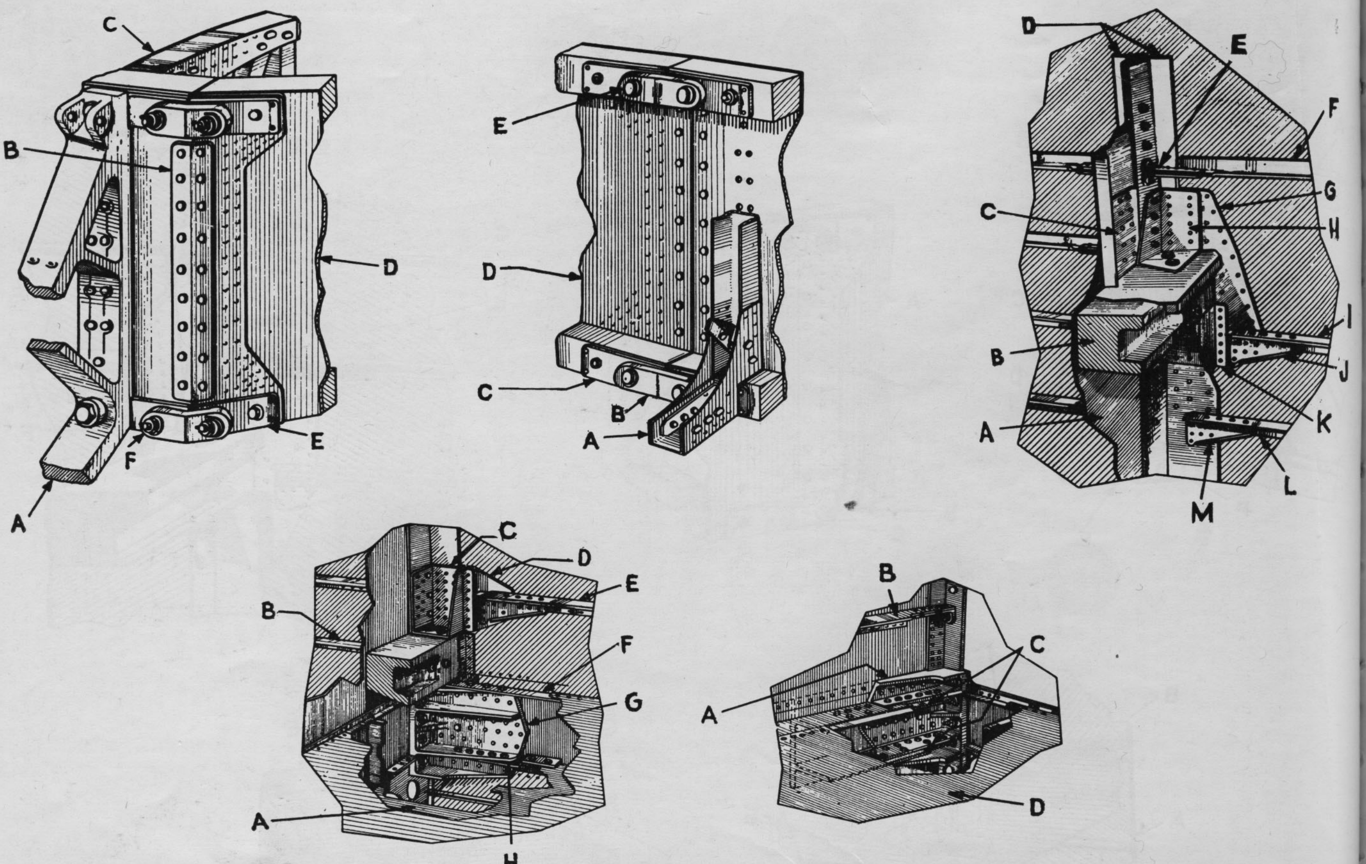


Fig. 3. Avro Lancaster spars are built up of trapezium-shaped extruded milled booms attached by nickel chrome and steel bolts to flat web alclad plates with sloping shape of the booms conforming to the top and bottom wing curves. The sketch at the upper left shows details, looking aft, of the front spar joint at the center section and outer panel, with landing gear support beam (*A*); web joint plate (*B*); engine rib (*C*); outer panel spar web (*D*); reinforcing plate (*E*); and steel shackle (*F*). The top center sketch shows the same area, but looking forward, with engine rib (*A*); steel shackle (*B*); reinforcing plate (*C*); outer panel spar web (*D*); and boom joint pin (*E*). The sketch at the upper right is the joint of the top front spar boom to the fuselage, with spar web (*A*); boom (*B*); web joint plate (*C*); fuselage formers (*D*); stringer attachment angle (*E*); stringer (*F*); gusset plate (*G*); shoe plate (*H*); stringer (*I*); stringer bracket (*J*); stringer bracket (*K*); and stringer and stringer bracket (*L*) and (*M*), respectively. The lower left sketch shows the lower boom-to-fuselage joint, looking forward, with floor bottom (*A*); stringer (*B*); shoe plate (*C*); gusset plate (*D*); stringer (*E*); fuselage longeron (*F*); longeron bracket (*G*); and strap plate (*H*). Lower right is the same looking aft, with longeron bracket (*A*); stringer (*B*); strap plates (*C*); and floor top (*D*).

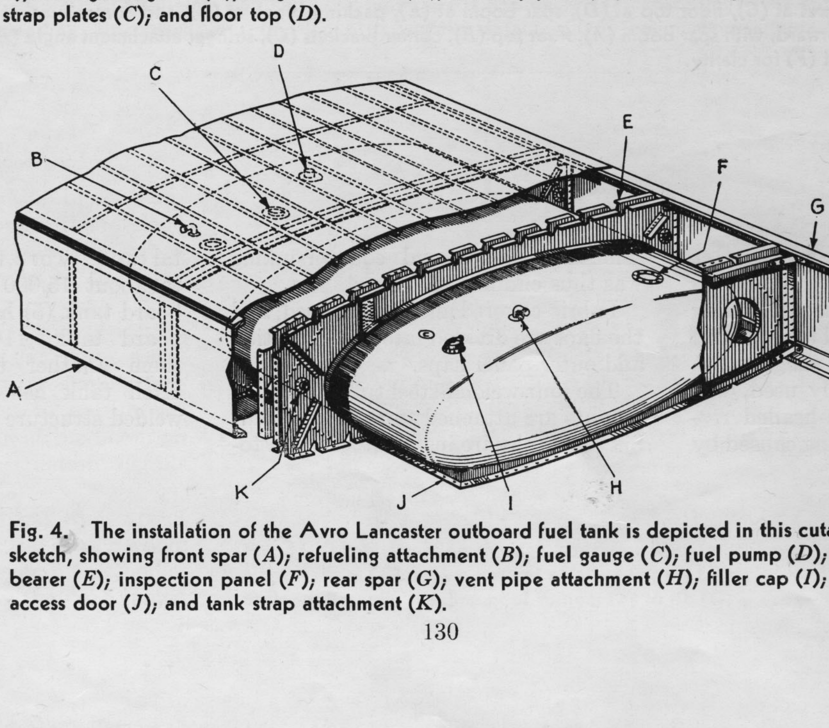


Fig. 4. The installation of the Avro Lancaster outboard fuel tank is depicted in this cutaway sketch, showing front spar (*A*); refueling attachment (*B*); fuel gauge (*C*); fuel pump (*D*); tank bearer (*E*); inspection panel (*F*); rear spar (*G*); vent pipe attachment (*H*); filler cap (*I*); tank access door (*J*); and tank strap attachment (*K*).

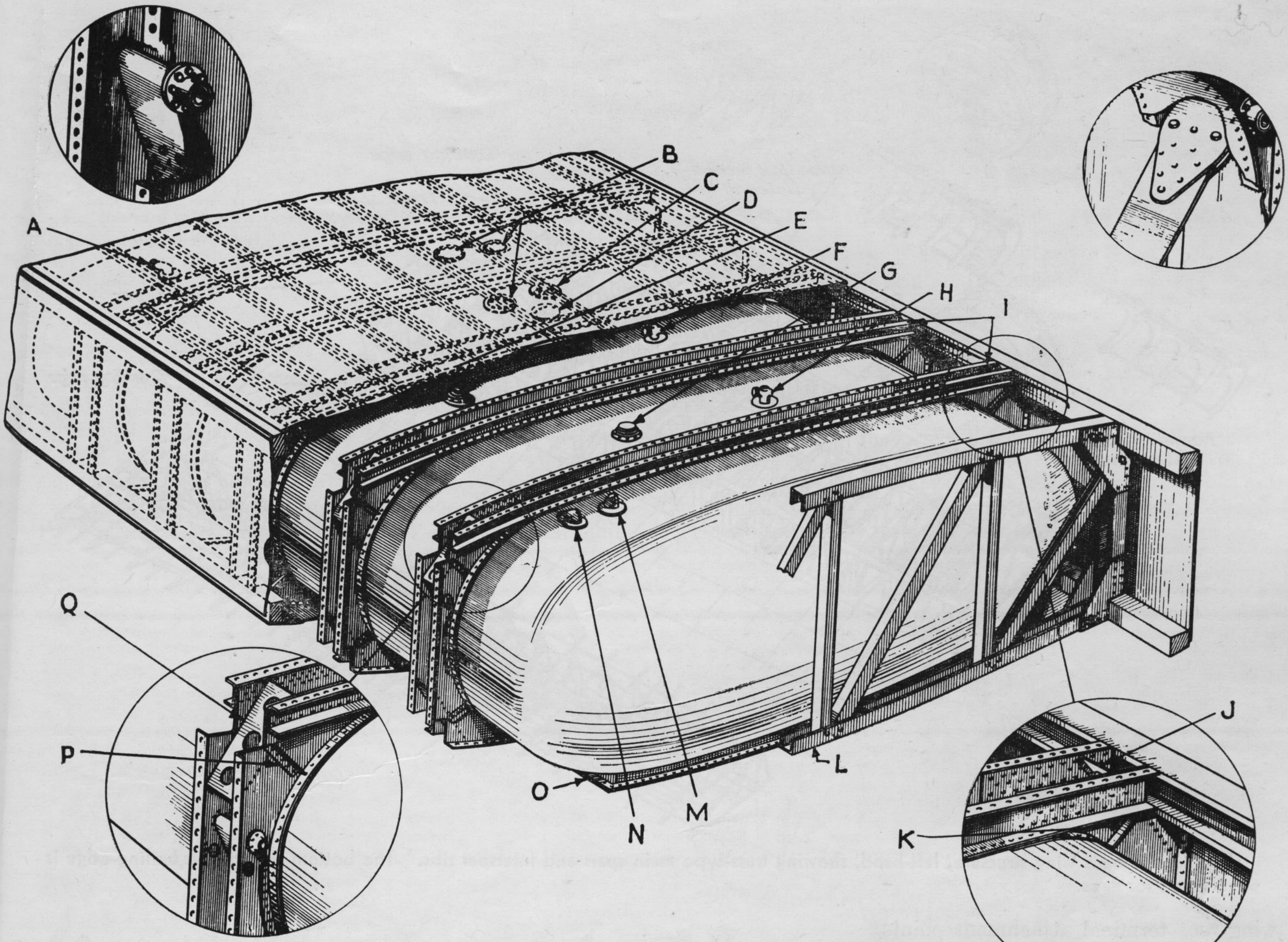


Fig. 5. Cutaway view shows the method of mounting the Lancaster inboard wing fuel tank, with refueling connection (*A*); inspection doors in tank (*B*); jettison adapter (*C*); air valve (*D*); filler cap (*E*); fuel pump (*F*); fuel gauge (*G*); pump (*H*); tank bearers (*I*)—also shown enlarged in the circle at the lower right with diaphragm at (*J*) and stiffening angle at (*K*)—inboard engine rib (*L*); air vent (*M*); refueling connection (*N*); and tank access door (*O*). The circled sketch at the lower left is an enlarged view of a tank rib at the front spar, with stiffening angle shown at (*P*) and diaphragm at (*Q*). The circled sketches at the upper left and right depict, respectively, the tank strap attachment on the tank rib at the front and rear spars.

Boeing B-17

Of semimonocoque construction, and with a span of 103 ft 9.38 in., the B-17 wing contains two truss-type main spars (1) which, while more difficult to manufacture, are lighter than web construction and contribute about 30 per cent of the wing bending strength. Its strength is well distributed as attested by the absence of wing failure after terrific battle damage in the Second World War.

Airfoil section combines NACA 0018 at the root with NACA 0010 at the tip. Wing area is 1,420 sq ft, and the root chord is 228 in. Tip chord is 106.7 in.; taper ratio 2.34:1; incidence 3½ deg; dihedral 4½ deg, and sweepback of leading edge is 8¼ deg. In taxi position, the wing chord angle to the ground line is 10¾ deg.

Located at 15 per cent of chord, the front spar joins the fuselage at an angle of 6 deg rearward of 90 deg from the plane's center line. The rear spar joins at the conventional 90 deg. Although the 6-deg angle of the front spar incurs a penalty in requiring a heavier rib or compression strut at the wing root, it is more than offset by the space gained between the spars and straight-line spanwise contour.

The spars consist of 25ST tubing spar chords connected by web members of square, barrel, or rectangular tubing joined to the chords by means of gussets. The inboard sections of the chord tubes have an inside taper in wall thickness from .54 at the inboard ends to .13 at the outboard ends. The outboard sections are of constant-gauge square tubing.

Truss-type interspar ribs, spaced 15 to 18 in. apart, connect the two spars. Ribs are built up of 24ST channel chords and tubular diagonal members attached by gusset plates. The ribs, in turn, are joined to the spars by riveted gussets (2).

At places of heavy stress, such as the

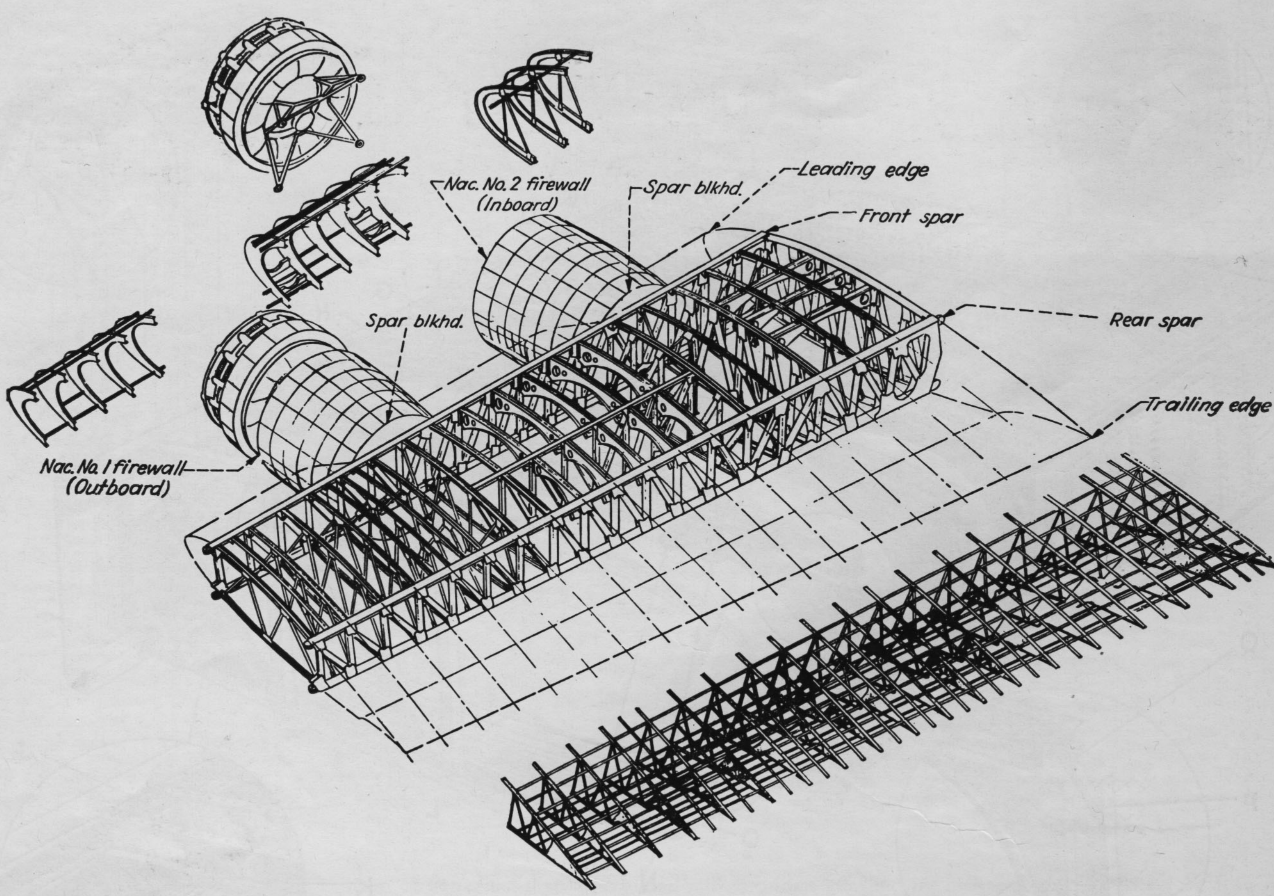


Fig. 1. Inboard wing structure, left-hand, showing truss-type main spars and interspar ribs. The bottom side of the trailing-edge is recessed for flaps.

wing root terminal attachment points and landing gear mounting points, unusually heavy ribs for compression struts are provided. Heavier compression struts also are located at intervals among the lighter ribs to distribute torsion better.

Over the truss structure of the wing is a layer of corrugated 24ST, ranging in thickness from .064 inboard to .016 outboard, laid with the corrugations running parallel to the rear spar and riveted to the 24ST alclad skin with flush-type rivets forward of the front spar and with brazier rivets aft of that line.

Wing construction is in six sections: right and left inboard, right and left outboard (3), and tips. The entire assembly is attached to the fuselage by terminals of highly heat-treated, machined-steel forgings connected to the wing by bolts. Heavy taper pins make up the terminal connections.

Engine nacelles are carried by the inboard sections and are connected to the wing by bulkheads at the front spar and fairing angles around the wing-nacelle

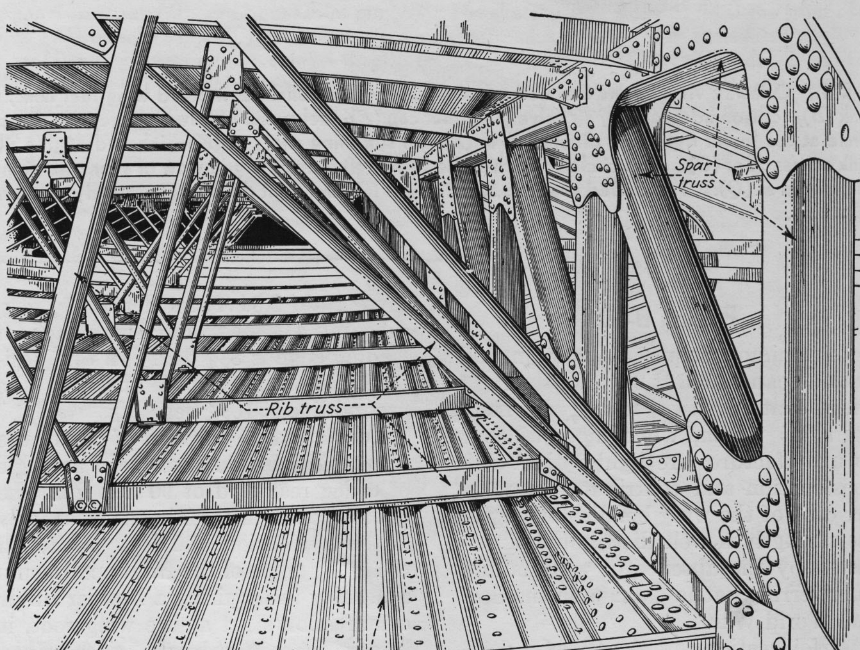


Fig. 2. Close-up of the internal wing structure showing attachment details of spar truss, rib truss, and corrugations.

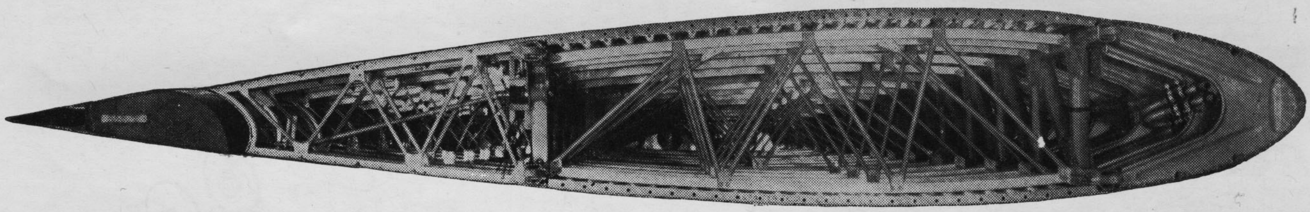


Fig. 3. Inboard end view of an outboard wing panel. Note the attaching terminals at the upper and lower points of the spars, and the corrugations under the skin.

intersection. Inboard nacelles, housing the main wheels, have wheel wells reinforced by two large fore-and-aft heavy formed channels that tie into heavy steel landing gear support forgings which are securely attached to the wing surface and compression ribs. (This terminal connection of steel bolts and rivets aids in the nacelle attachment to the wing for the inboard nacelles only.)

Aluminum alloy terminals connected by taper pins are used at terminal connections between the inboard and outboard wing panels. The wing tip has four terminal points of welded steel or magnesium alloy and is secured to the outboard wing panel by means of steel bolts.

Conventional fabric-covered D-nose-type ailerons (4) have an area of 60.2 sq ft to the hinge line, and an angular movement of 12 deg both up and down. The distance from the

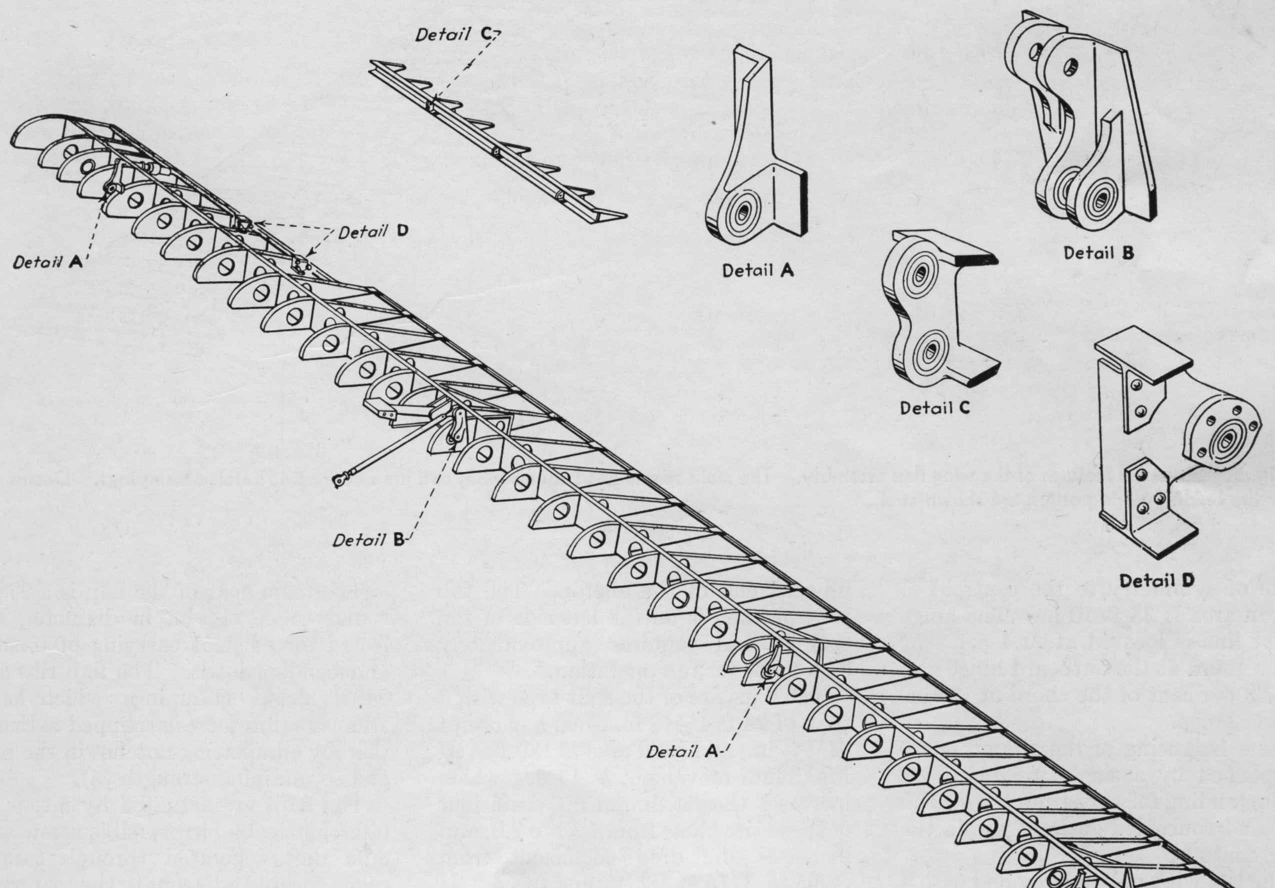


Fig. 4. Structural details of the aileron assembly. Hinge fitting is shown at detail *A*; control hinge for attachment of the actuating arm at detail *B*; and trim tab control hinge and hinge details at *C* and *D*, respectively.

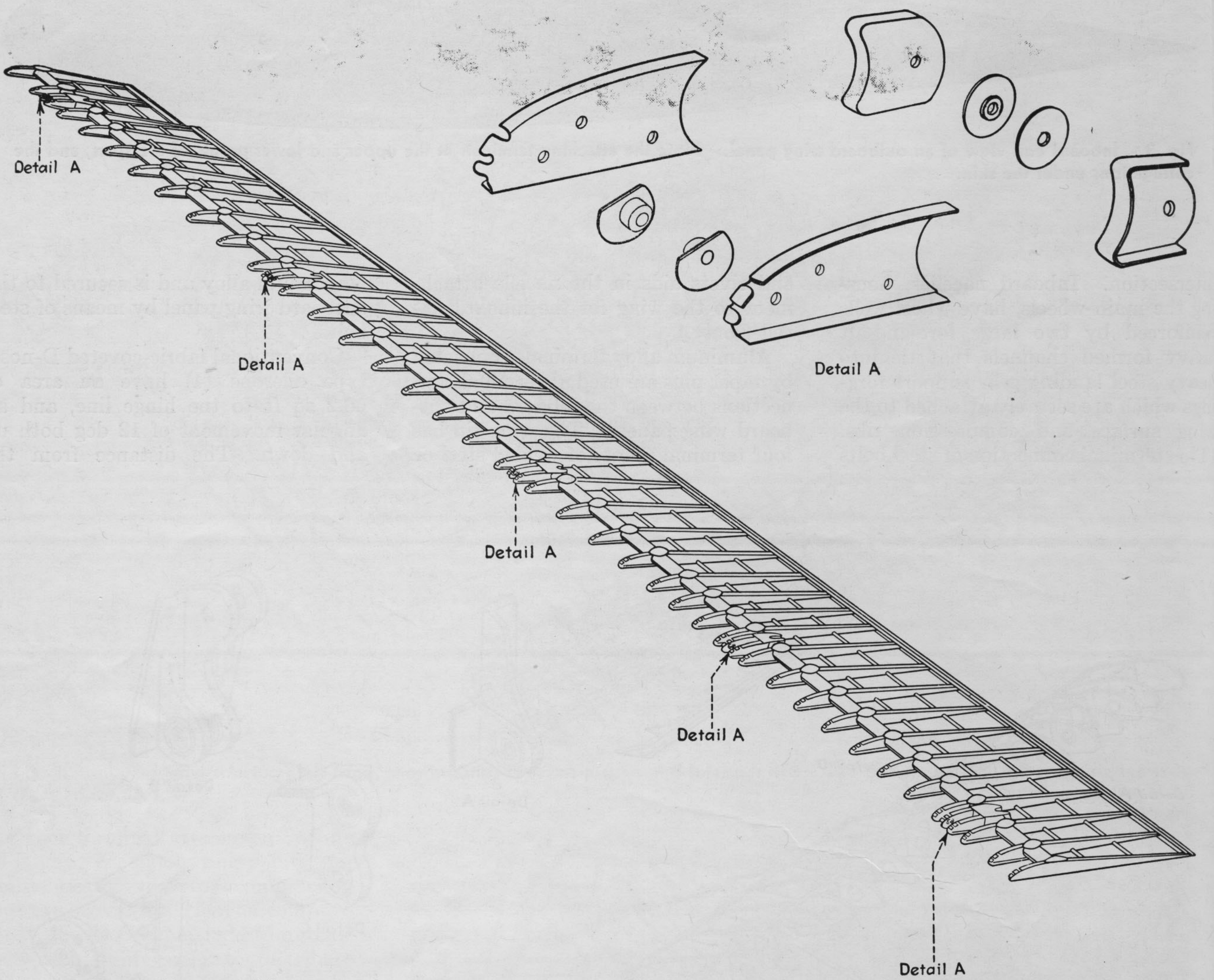


Fig. 5. Structural features of the wing flap assembly. The main spar is 24ST round tube, and the ribs are 24ST alclad stampings. Details of the leading-edge portion are shown at *A*.

plane of symmetry to the centroid of aileron area is 38 ft 10 in. The hinge center line is located at 21.4 per cent of the chord at the outboard hinge and at 27.3 per cent of the chord at the inboard hinge.

Mass balancing of the aileron is accomplished by a single weight on an arm extending forward from the aileron spar and concealed entirely within the wing contour.

The left wing only is provided with a trim tab. The tab has an area of 2.64 sq ft, angular movement both up and down of 15 deg, and is located at the inboard end of the aileron. The tab control knob is on the left side of the cockpit and requires approximately 3.76 turns for full operation.

The flaps are of the split type with a span of 24 ft 4$^{15}\!/_{16}$ in. each, a chord of 34$^{13}\!/_{32}$ in., and total area of 139.1 sq ft. Maximum movement is 45 deg which increases the maximum lift coefficient of the entire plane from 1.53 to 2.0, and increases the drag coefficient from .1095 to .1775 at 1.2 stalling speed. It also increases the gliding angle from 5°39′ to 7°20′ at 1.2 stalling speed and decreases the landing speed 9 mph.

The main spar of the flap is a 24ST round tube, 2½ in. in diameter, selected for efficient carrying of torsion and bending loads. The flap ribs are 24ST alclad stampings which have stiffeners (intercostals) clipped to them, thereby eliminating notches in the ribs and so retaining strength (5).

The flaps are actuated by means of interchangeable, irreversible screw and nuts units operated through torque tubes, located adjacent to the rear wing spar and powered by an electric motor. They can be raised or lowered at 126 mph in 15 to 30 sec.

Boeing B-29

The B-29 engine nacelles in the Superfortress wing are greater in diameter than fuselages of many smaller aircraft. The nacelles are of built-up construction with tubular members. Fairing extends over the top of the wing (1).

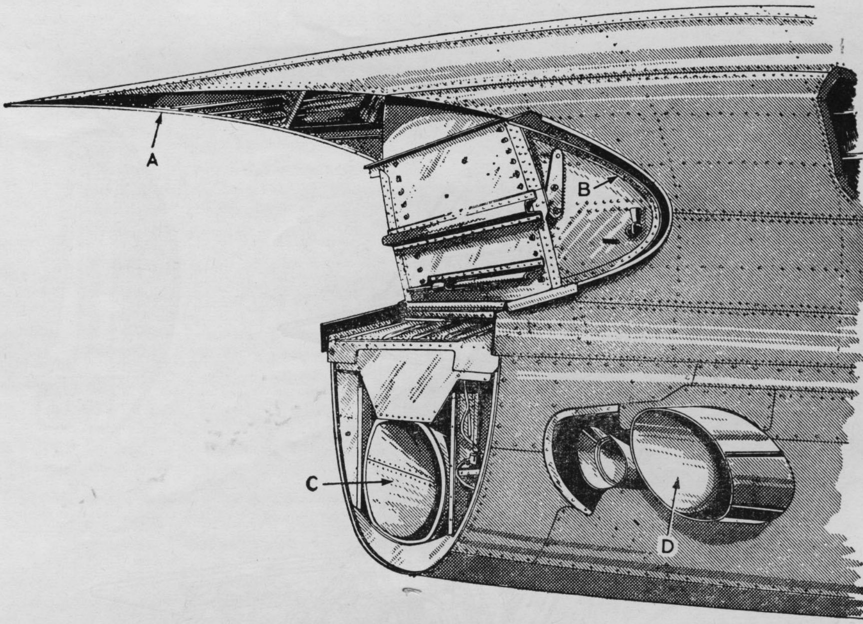


Fig. 1. Details of the aft end of a B-29 engine nacelle, showing fairing *A* which extends over the top of the wing, the leading edge of which fits at *B*. The air duct is shown at *C*, and the end of the engine exhaust stack is at *D*.

Douglas C-54

The wing center section of the C-54 carries the four engine nacelles and forms a continuous section through the fuselage section (1).

The wing is of two-spar construction with ribs and stringers employed between the front and center spars, and ribs aft of the center spar (2).

Landing gear fittings are attached to the front and center spars (3).

The flaps are constructed with deep-drawn ribs (4) and are provided with four hinge link base forgings of aluminum alloy.

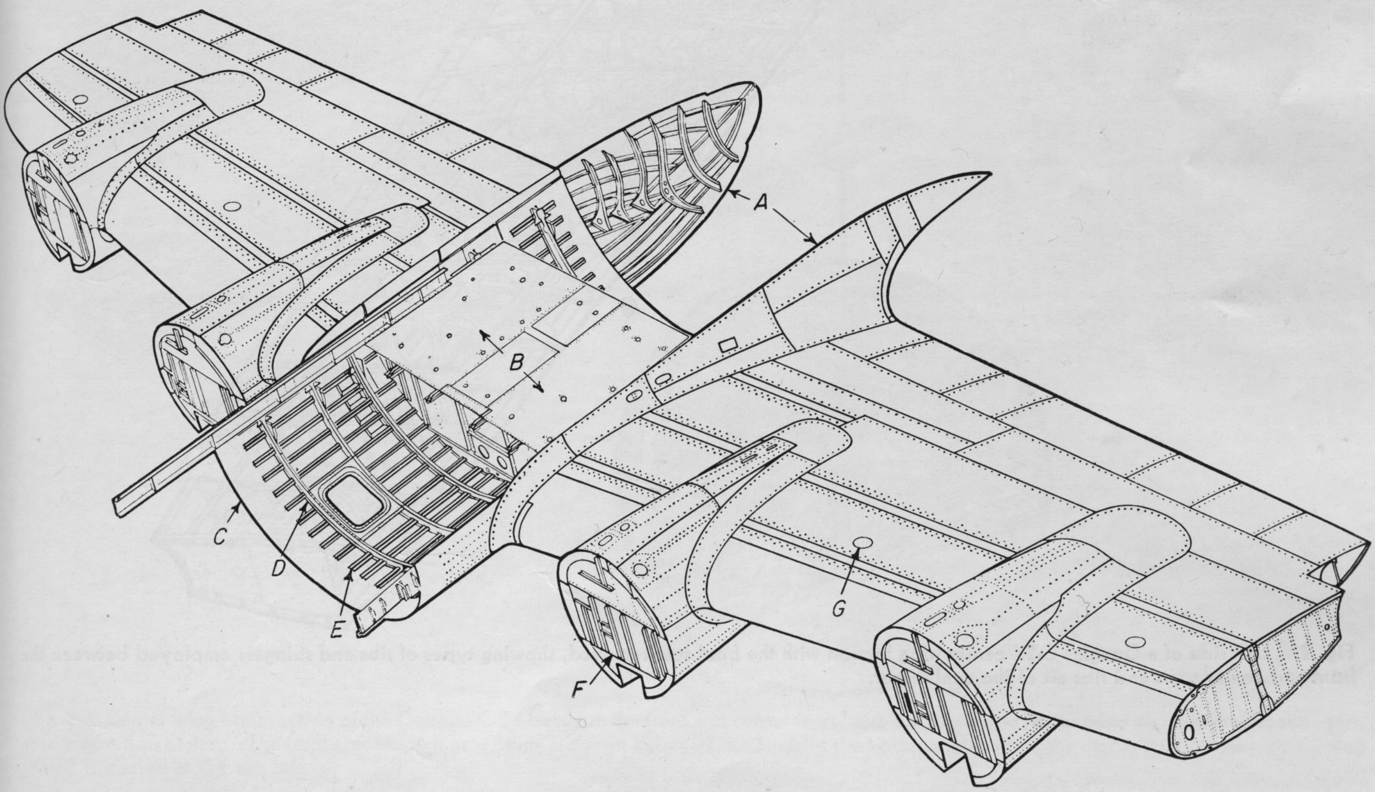


Fig. 1. Douglas C-54 center wing panel assembly, showing wing-to-fuselage fillets (*A*); cargo floor panel (*B*); lower fuselage section (*C*) with ring frame sections (*D*); hat-section longerons (*E*); engine nacelle (*F*); integral fuel-tank filler access door (*G*).

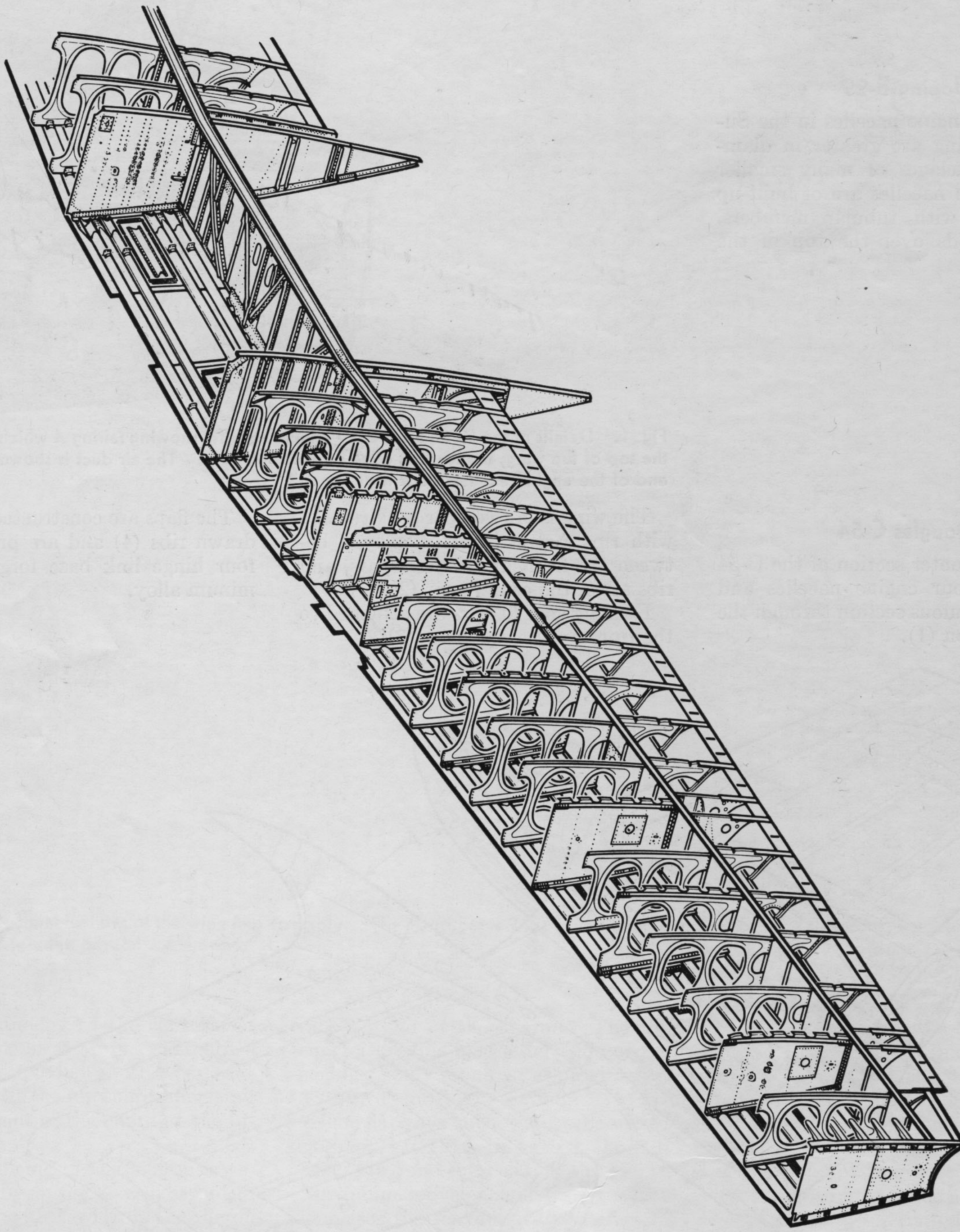


Fig. 2. Left side of a Douglas C-54 center wing section with the front spar removed, showing types of ribs and stringers employed between the front and center spars and ribs aft of the center spar.

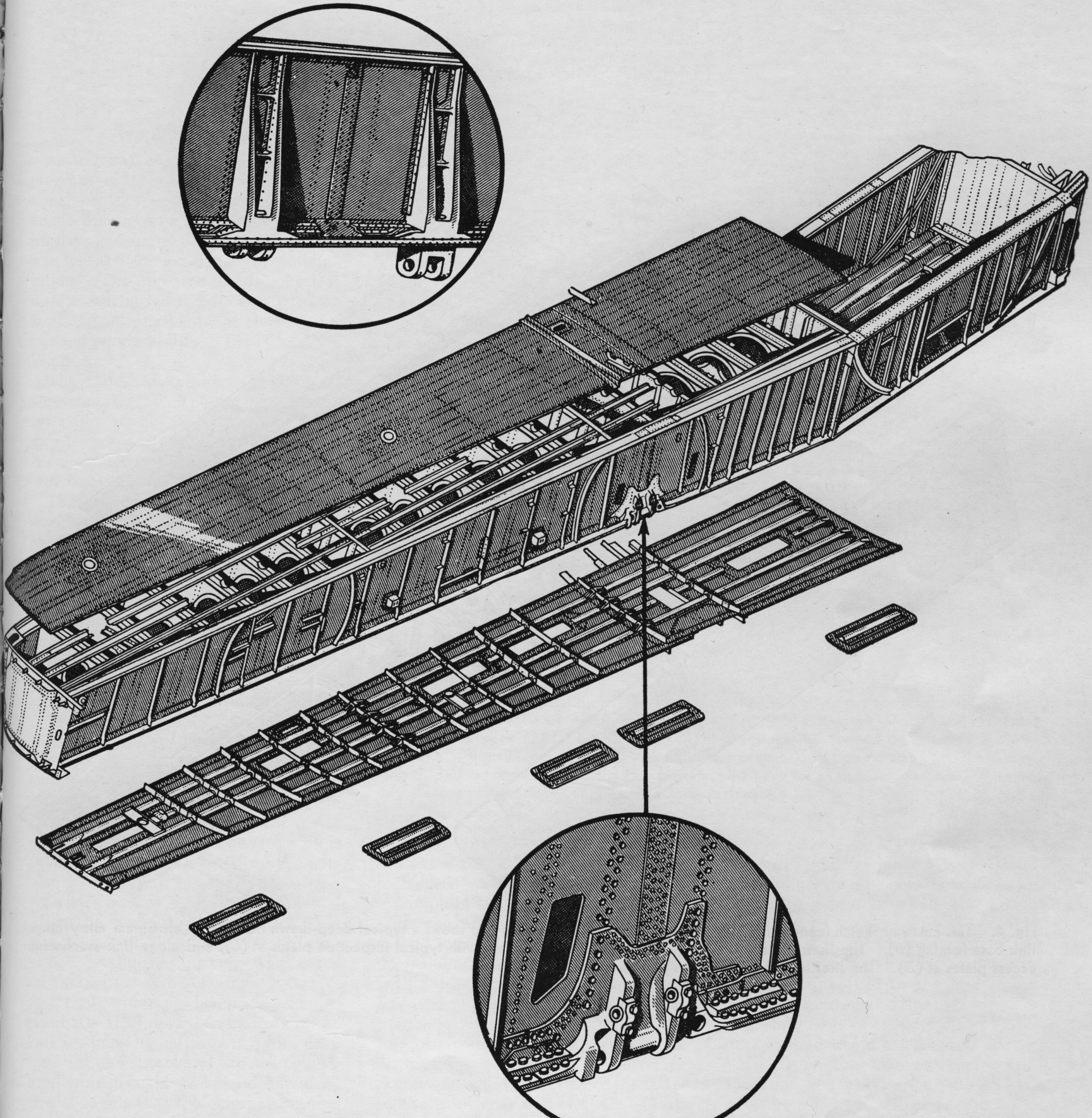


Fig. 3. Center wing front section of the Douglas C-54 between the front and center spars, with the lower skin removed to show stringers, stiffeners, and inspection plates. The front spar landing gear fitting is shown enlarged in a circle at the bottom right, while the center spar landing gear fitting detail is circled at the top left.

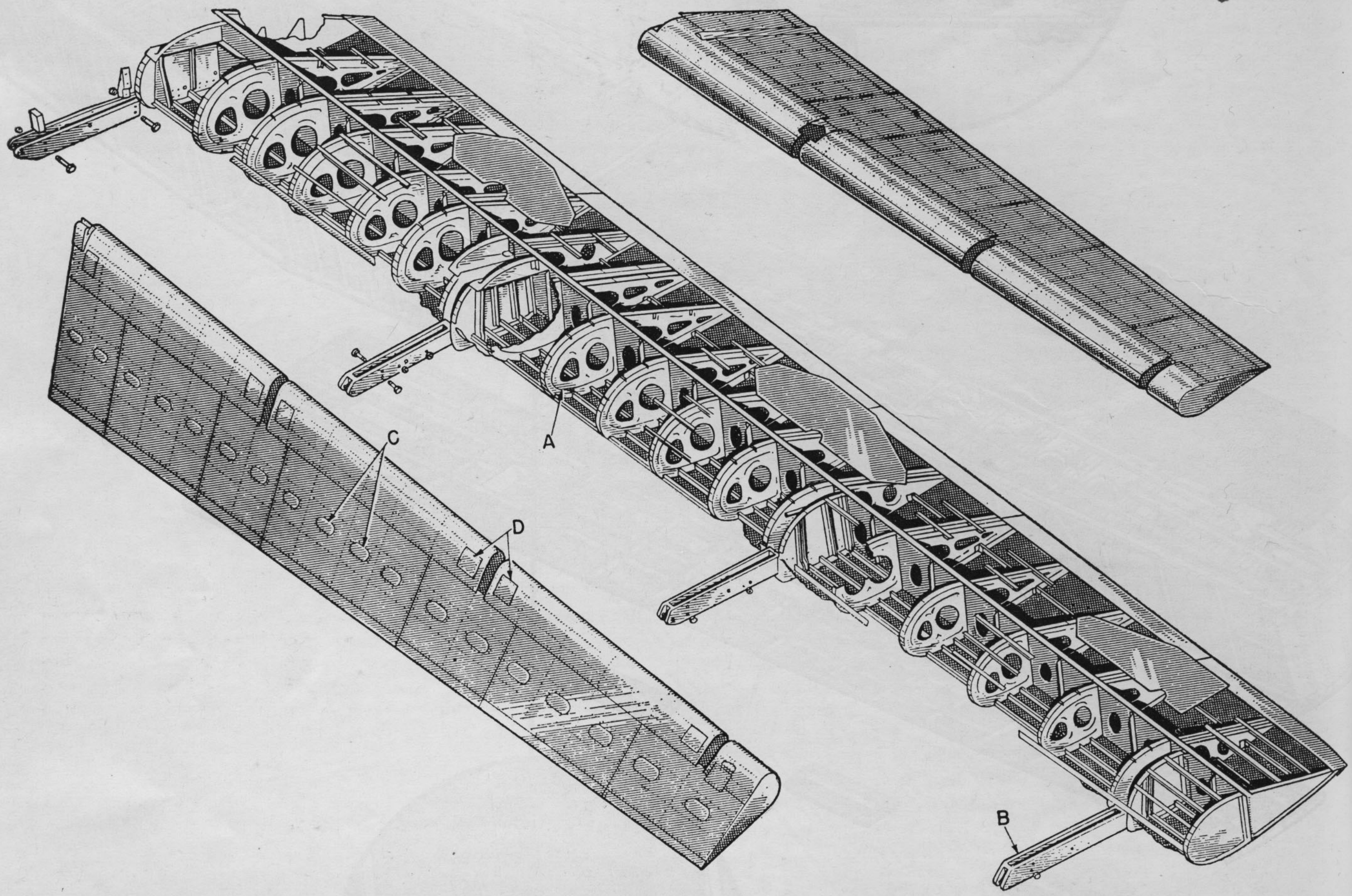


Fig. 4. This cutaway sketch (center) of a Douglas C-54 Skymaster left wing flap shows a typical deep-drawn rib (*A*) and aluminum alloy hinge link base forging (*B*). The sketch at the left shows the lower skin of the flap, with typical inspection plates at (*C*), and hinge link mechanism access plates at (*D*). The sketch at the right shows an upper surface of the flap.

Chapter III. EMPENNAGE DESIGN

PART 1. SINGLE-ENGINE AIRCRAFT

Republic Seabee

As an initial step in the development program of the Seabee, the conventional prototype stabilizer—a fair example of a costly all-metal structure consisting of spars, ribs, and stringers—was selected for experimental simplification. The aim was to effect radical manufacturing cost reduction without sacrificing strength-weight characteristics and serviceability. (See Chap. II, Wings.)

The simplified stabilizer (1)* evolved approximately 6 ft long, with average chord of 1½ ft—consists of front and rear spars and inboard end rib. All material is R-301W, requiring no heat-treatment.

The front spar, the only internal member of the stabilizer structure, is an .025 channel section with lightening holes having simple flanges for stiffness. The rear spar is an .091 channel section. Both spars have straight-line taper and can be made on a mechanical press or on a bending brake. A flat bearing plate is attached at the inboard end of each spar for connection to the hull structure.

The inboard end rib (2)—.025 gauge—has simple flanged lightening holes. A slot in the rib allows the front spar to pass through without interrupting the rib member, and the attachment of the latter to the spar is made via the metal portion displaced from the slot. It is to be noted that the skin forms the outboard connection for the spars of the stabilizer unit.

On the conventional stabilizer, skin was .020 24ST alclad, whereas the simplified stabilizer, having the same outline, has skin of .025 R-301W. External stiffening beads, serving to eliminate the internal framework of the conventional structure, are ¼ in. deep by 4 in. on centers and are not considered objectionable as speed-impeders. It also is felt that the external beading lends a decorative touch to the plane surfaces. The actual test on the prototype plane, with and without beading (beads were simulated by wooden strips attached to the wing and tail surfaces), showed a reduction of but 3 mph at high speed—a loss offset by a reduction of 2 mph in stalling speed.

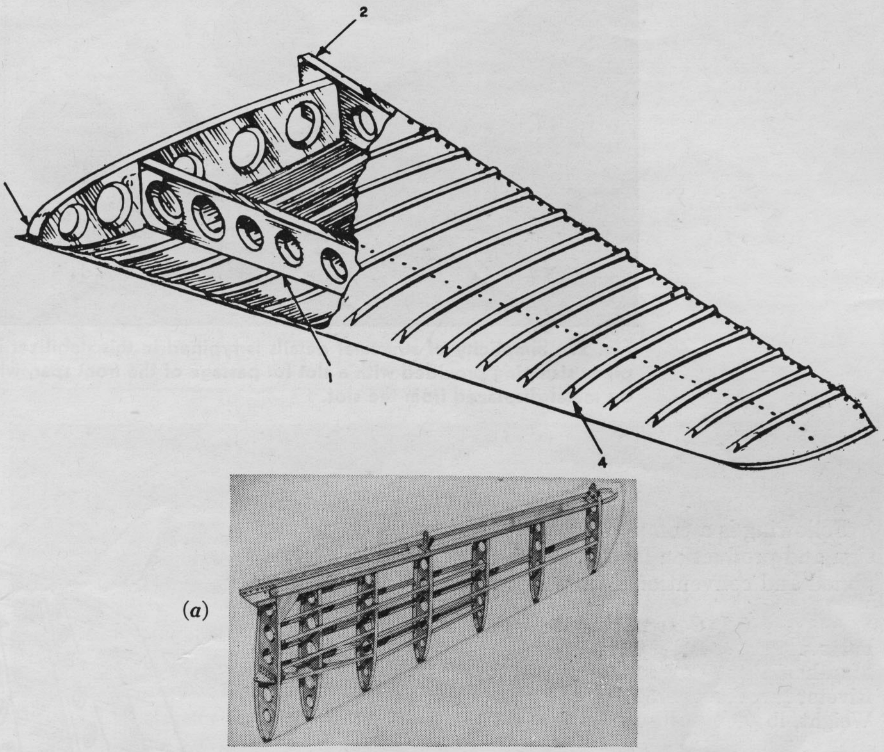


Fig. 1. The simplified stabilizer seen here presents a marked contrast to the comparatively complicated conventional design shown at *a*. Simplified design components are (1) front spar; (2) rear spar; (3) inboard end rib; (4) single-piece skin formed on camel-back draw die, with ¼-in. stiffening beads serving to replace conventional frame members. The skin is also shaped to form an integral tip, thus obviating the need for an outboard end rib. Assembly is accomplished almost entirely by automatic riveting.

In assembly, the front spar is attached to the inboard end rib as a first operation. This unit is then placed within the skin envelope whose sections have been preassembled on an automatic riveting machine with a single row of rivets. Accessibility from the open end at the rear of the envelope permits automatic riveting of the latter to the front spar and end rib. Next, the rear spar is installed and automatically riveted to the skin to form the rear closure of the structure. The tip is formed with an external flange, also automatically riveted.

Thus the entire assembly is automatically joined—aside from the attachment of stabilizer hinges (bolted) and other minor hand operations, a fairly typical procedure for all the airfoil structures on the Seabee. This simple assembly is in marked contrast to the complicated manual, slow, and costly procedure involved in the fabrication of the conventional structure.

A static test of the simplified stabilizer showed about 10 per cent higher strength over the conventional prototype unit, and it also disclosed very satisfactory rigidity. Most important—since it made possible such fast and cost-saving production methods (the replacement price of the stabilizer panel complete assembly, including attachment parts, was expected to be under $35 at the time)—was the justification of a new approach in stress analysis.

* The numbers in parentheses refer to the illustrations.

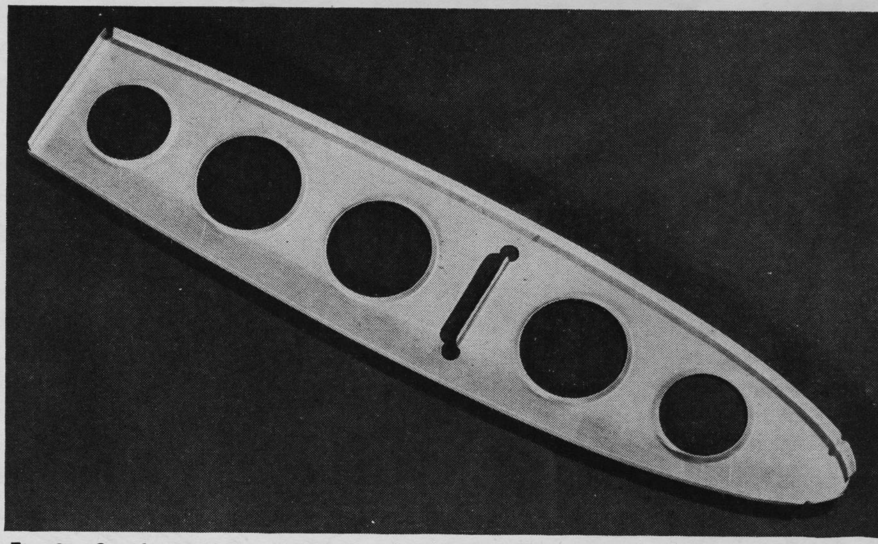


Fig. 2. Simplicity of structural details is typified in this stabilizer inboard end rib, a single-piece stamping provided with a slot for passage of the front spar, which is attached to the rib by metal displaced from the slot.

Following is a comparison of the design and production factors of the simplified and conventional stabilizers:

	Conventional	*Simplified*
Parts	42	9
Man-hours	14.2	2.7
Rivets	521	160
Weight, lb	13	13

Except for size and shape, the elevators and rudder, as well as other movable surfaces treated in other chapters, are fundamentally identical in construction. Each consists of a single beaded skin folded upon itself and joined at the trailing edge, and each has a single stamped channel spar member near the leading edge.

The elevator (4) has only one rib—at the inboard end—bolted to the operating torque tube extending between left and right units. No outboard end rib is used because the tip is formed from the skin as a continuation of the T.E. The latter is cut out for a flat stock trim tab at the inboard end, the tab being attached by a piano hinge.

The upper and lower tips on the rudder (3) are fabricated similar to the elevator tip, hence obviating need for end ribs.

Approximate dimensions of the rudder (double tapered in planform): 8½ ft long by 18 in. at the maximum chord by 4 in. in average thickness at the spar.

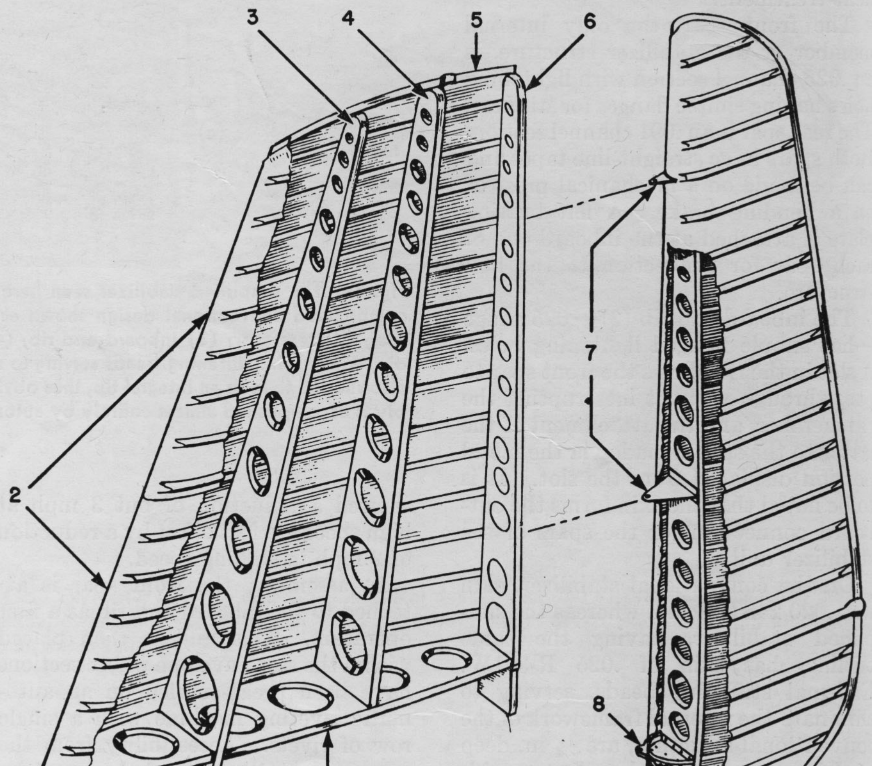


Fig. 3. Fin and rudder assembly: (1) fin bottom end rib; (2) wrap-around skin; (3) front spar; (4) center spar; (5) integral skin tip; (6) rear spar; (7) rudder hinge fitting; (8) combination hinge and horn fitting; (9) spar; (10) wrap-around skin joined at the T.E. It was contemplated to build a rudder of left and right clamshell sections joined along external flanges at both L.E. and T.E. (around the entire periphery), thus eliminating the spar.

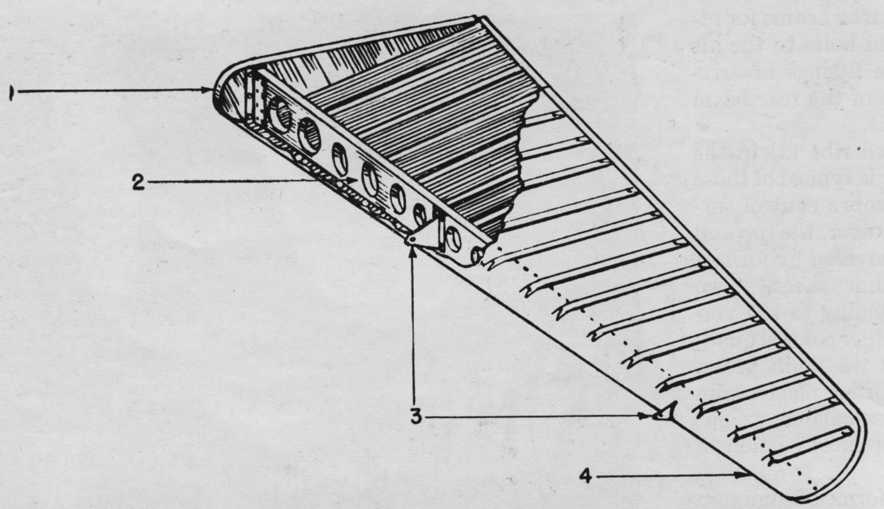


Fig. 4. The simple make-up features of the elevator structure are (1) inboard end rib, (2) spar; (3) extruded hinge fitting; (4) single-piece wrap-around skin joined at the T.E. and having an integral skin tip to eliminate the end rib.

Bell P-39 Airacobra

Constructed as a single unit with sections cut away in the center to permit access of the vertical stabilizer to the fuselage, the horizontal stabilizer of the P-39 is a twin-spar structure of conventional stressed-skin design.

The forward beam is built in three flanged sections formed of heavy gauge sheet. The center section is a short member, perpendicular to the aircraft center line, to which are attached two outer beam sections with a pronounced sweepback, approximately parallel to the leading edge. A series of false ribs of formed and blanked aluminum sections form the L.E.

The rear beam, formed from .072-gauge sheet, is in two half sections spliced with a riveted aluminum plate. Each half section has a solid formed sheet tip attached with rivets. About halfway from the center on each side, forged aluminum alloy steel hinge fittings for the elevators are fastened to the rear beam.

The front and rear beam are tied together with a series of blanked and formed bulkheads. Z-shaped stringers support the flush-riveted skin. L.E. skin is a single formed section on each side, extending from the top flange of the front beam around the forming ribs to the bottom flange.

From the front beam to the rear edge, the skin is in four formed-aluminum sheet sections, two on each side, top and bottom. Stabilizer tips are single formed-aluminum sections riveted to the single rib of the stabilizer proper. Four threaded studs, two on each beam, provide for stabilizer attachment to the fuselage with lock nuts.

Similar in construction to the ailerons, the elevators are fabric-covered. Right and left elements are joined at the control quadrant by tubular steel members spliced by forged, flanged steel collars. The left elevator (1) has a trim tab fastened to an auxiliary beam just forward and inboard of the trailing edge section. Two hinge settings are installed on the main beam and attached to the horizontal stabilizer. A mass-balance, tubular-shaped weight, used for dynamic and static balancing, is located in the foremost section of the L.E.

The vertical stabilizer is similar in construction to the horizontal stabilizer, except that beams are of one-piece construction. A hole is cut in the skin on both sides for the installation of the navigation light. Cast fittings are installed on the projecting

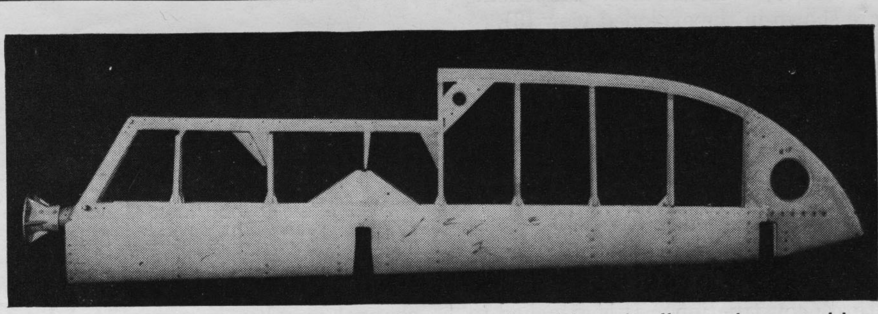


Fig. 1. Left elevator showing provision for a trim tab and forged collar on the control bar.

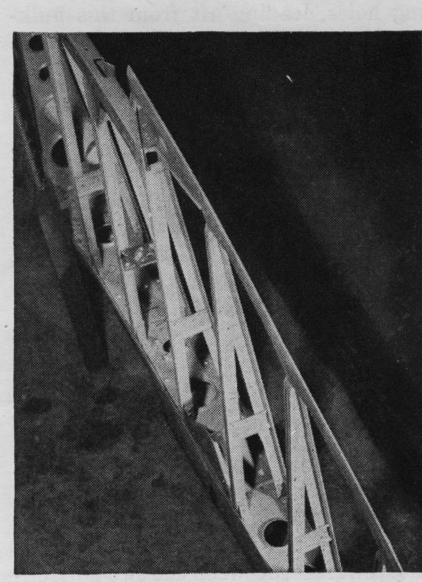


Fig. 2. Close-up of extruded ribs used on the rudder which are typical of those used on all control surface structures.

ends of the main and rear beams for attachment by nuts and bolts to the aft fuselage. Two hinge fittings are riveted to the aft flange of the rear beam for rudder attachment.

The use of extruded ribs (2) in the fabric-covered rudder is typical of those employed in all Airacobra control surface structures. However, the top and bottom portions are covered by formed and beaded aluminum sheet. Two hinge fittings for fastening to the vertical stabilizer and rudder control quadrant are installed on the main beam. Auxiliary beam supports a plastic trim tab, and a round mass-balance weight is mounted in the foremost section of the L.E.

Nine pieces of formed-aluminum sheet and formers comprise the empennage fillet assembly, which is attached by flush screws and channel nuts.

The major tail assembly components are shown in the exploded view (3).

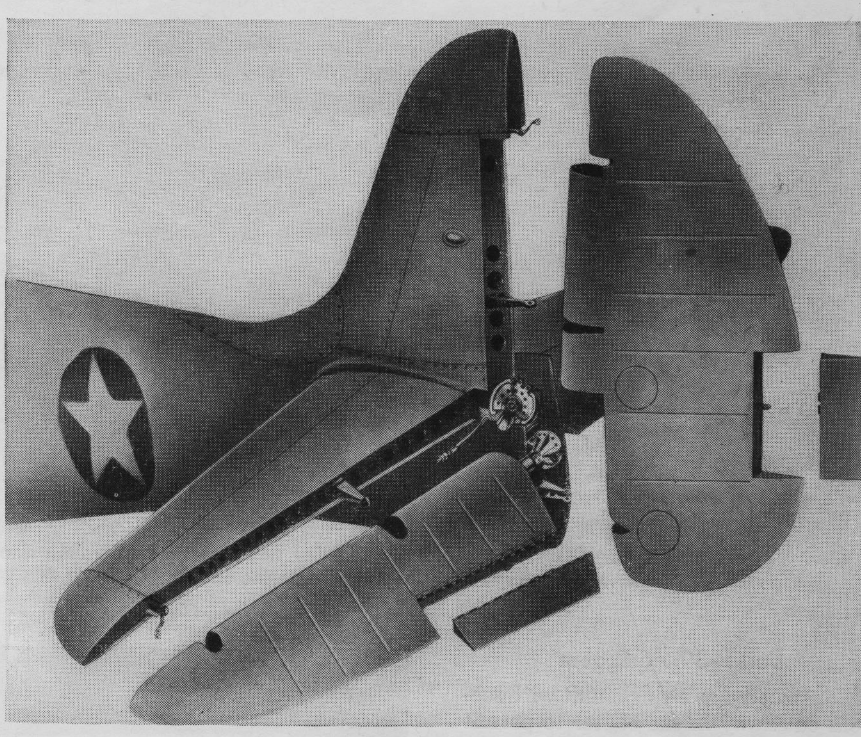


Fig. 3. Exploded view of an Airacobra tail, showing the attachment of units and elevator torque tube.

Focke-Wulfe FW-190

The FW-190 empennage is one of the outstanding examples of simple yet sturdy construction. It is attached to the aft fuselage section at bulkhead 14 by mating, flanged bulkheads through a series of closely spaced bolts (1).

A stamped, flanged rib, with lightening holes, leading aft from this bulkhead, extends from side to side. Another full-width rib is 7⅜ in. lower. The stabilizer goes through the fuselage between these ribs.

Both ribs intersect a diagonal member which is the heart of the empennage, for it carries tail-wheel loads on the ground and, once the aircraft is airborne, carries both fin-and-rudder and stabilizer-and-elevator loads.

Starting at the bottom skin 18¾ in. aft of the attaching bulkhead, this member extends up and aft 63½ in. to the top vertical fin rib (which extends aft to support the top rudder hinge) at the base of the detachable vertical fin tip. Nine inches from this member's lower end, on the aft side, is riveted a fitting to which is attached the front end of the tail-wheel drag yoke. On the front face, between the two horizontal ribs previously mentioned, is riveted a forged hexagonal fitting to which the stabilizer rear spar attaches.

Above the top horizontal rib, on the aft face, is riveted a 20-in. double channel member which forms the guide rails for the tail-wheel retracting unit. The channel member is surmounted by a plate bearing a pulley, part of the retracting unit, and the top fin rib.

The topmost of the two horizontal ribs extends aft of the diagonal member 16¼ in., the middle rudder hinge being mounted at its end. The other horizontal rib, aft of the diagonal, extends downward at about 28 deg from the base of the stabilizer fitting to the bottom of the tail cone to support the lower rudder hinge. A vertical web plate of stamped, flanged alloy connects the two ribs at their aft ends.

Below the two horizontal ribs, three Z-shaped stringers on each side run from bulkhead 14 to the diagonal member, and a similar number are employed above.

At the fin's leading edge, the skin is crimped and riveted together with a series of five diamond-shaped, self-locking nuts inserted and riveted between the crimping. L.E. skin, a single sheet of formed aluminum alloy, is then fastened in place with flush flathead screws driven into the diamond nuts. Drilling of the two fin skin surfaces apparently is not a jig operation, for a study of several craft showed uneven spacing and lack of rivet alignment. In one plane, a difference even in rivet size was evident.

The skin aft of the diagonal member, between it and rudder hinge points, is of familiar double skin "waffle" construction, eliminating the need for stringers. A triangular inspection door, 30 in. high by 15 in. across the base, set in the left side of the fin gives quick access to the tail-wheel retracting unit and top of the oleo shock strut. Two screw-driven locks are used. The piano hinge along the forward edge carries hinge springs to keep the door closed. These and the hinges are sealed in fabric.

Later models of the FW-190 reveal that additional web plates have been installed between the horizontal ribs behind and below the stabilizer fitting to distribute better the stabilizer-elevator and tail-wheel loads, indicating failures in the empennage in earlier models from various causes.

The rudder, dynamic and mass-balanced, is built round a single spar of stamped, flanged aluminum to which are riveted the three hinge fittings. The L.E. is flush-riveted to the spar, and the ribs have rounded gusset plates. Also of metal, the trailing edge is fabric-covered. Unlike most modern fighters, the rudder trim of the FW-190 was adjustable only on the

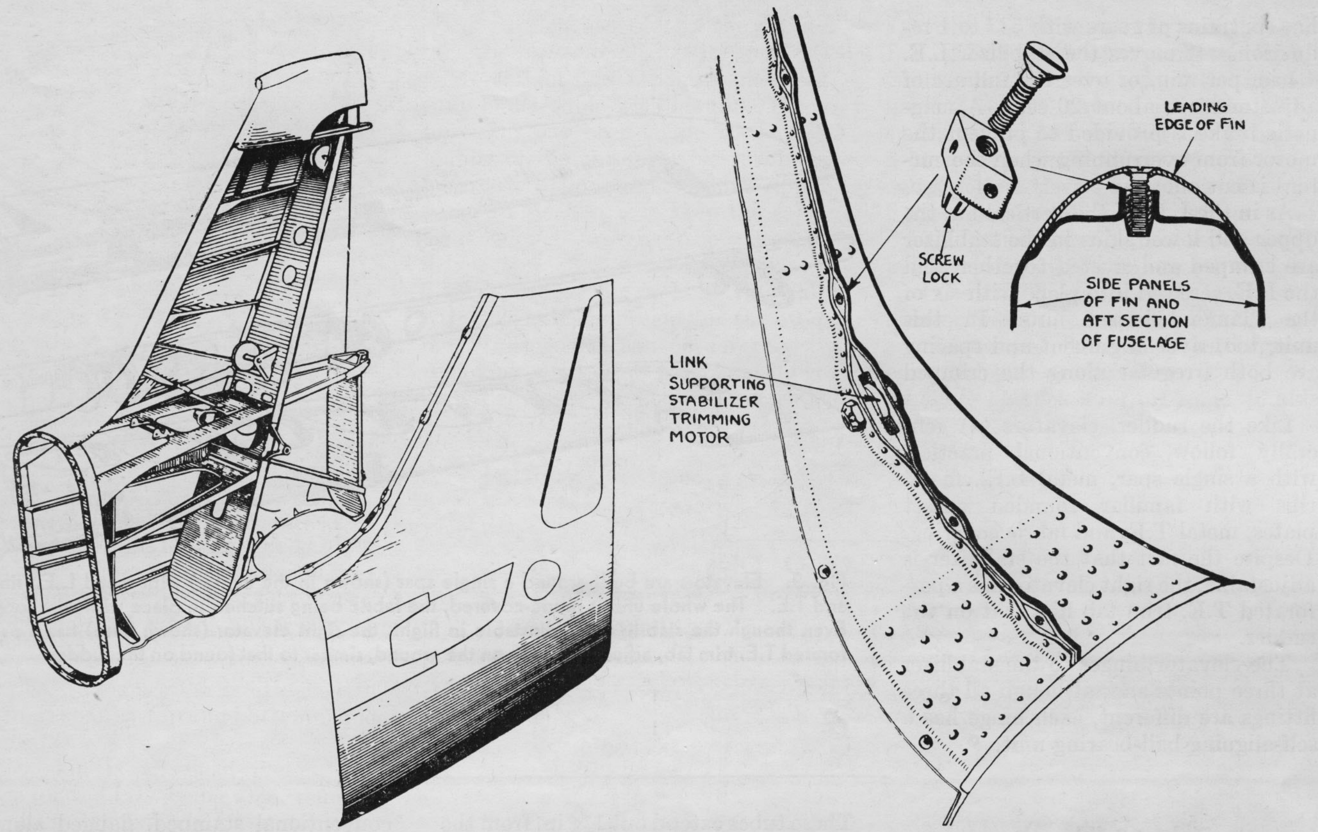


Fig. 1. Cutaway view (left) of the empennage and integral vertical fin. This section bolts to the aft fuselage section at bulkhead 14. The diagonal structural member is the heart of this section, for it supports tail-wheel loads when the craft is on ground and supports fin, rudder, stabilizer, and elevator loads when the ship is air-borne. Two skins, extending from the bottom of the fuselage to the top horizontal rib at the base of the fin tip, are riveted together at the top along a vertical flange. Aft of the diagonal member and above the middle horizontal rib, the skins are of "waffle" construction. A hinged inspection door, 30 in. high by 15 in. across its base, is locked in place by special screw-driver-operated fasteners. The piano hinge and springs are protected by fabric covering. The sketch (above) gives details of the fin L.E., showing how two skins are riveted together along the vertical flange. Single formed-aluminum alloy fairing is fastened over the flange by flush screws driven into diamond-shaped safety nuts riveted between flanges. The same method is used for the L.E. of the stabilizer.

ground. Consisting simply of a 15- by 1-in. metal strip, it is riveted into the T.E. with a series of perforations to facilitate bending to the desired degree. Two types of tabs are used; some with slotted perforations, some with round holes.

The stabilizer (2) is full cantilever, single-spar all-metal construction, built as one unit except for detachable tips. There are seven floating ribs on each side. The stabilizer attaches to the aft edge to the diagonal member of the fin through the forged fitting previously noted, and hinges on pins that insert in self-aligning trunnions, for vertical trim of the craft is effected through adjusting the stabilizer.

On the center of the stabilizer's L.E. is a fitting attached to a yoke which, in turn, fastens to a screw jack and electric motor suspended by a ball-and-socket joint from the L.E. of the fin. This motor, which turns up 14,000 rpm,

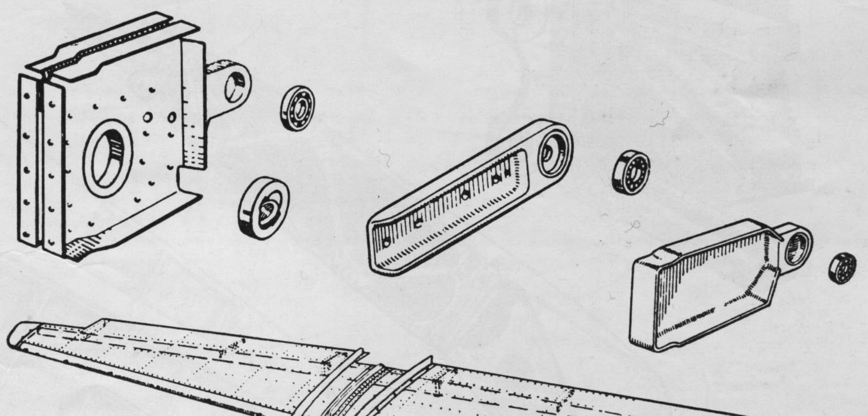


Fig. 2. The Focke-Wulfe FW-190 stabilizer is a single-spar full cantilever structure built in two halves and bolted together at the center line. The top and bottom skins are flanged and riveted together to form the front spar. The L.E. is attached like fairing on the vertical fin. Three ball-bearing supports for elevators are provided on each side (shown in detail in the sketches at the top). Formed tips are screwed into place with flathead screws in countersunk washers. Captured nuts in the flange of the outer rib hold them in place.

has six trains of gears with 533 to 1 reduction. It moves the stabilizer L.E. 4.1 in. per min, or over the full arc of adjustment in about 20 sec. A magnetic brake is provided to prevent the motor from overrunning when the current is cut off.

As in the L.E. of the vertical fin, the upper and lower skins in the stabilizer are crimped and riveted together, and the L.E. screwed into place with six of the diamond-shaped nuts. In this unit, too, rivet alignment and spacing are both irregular along the crimped skin.

Like the rudder, elevators (3) generally follow conventional practice, with a single spar, metal L.E., metal ribs with familiar rounded gusset plates, metal T.E. and fabric covering. Despite the fact that the stabilizer is adjustable, the right elevator has a perforated T.E. trim tab like that on the rudder.

The elevator hinges to the stabilizer at three points and, although all three fittings are different, each hinge has a self-aligning ball-bearing unit.

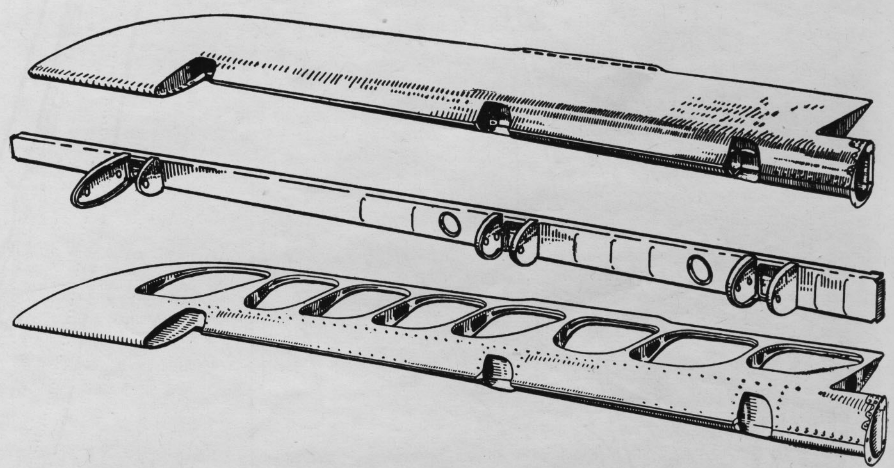


Fig. 3. Elevators are built around a single spar (shown in the center) with metal L.E., ribs, and T.E. The whole unit is fabric-covered, the fabric being stitched in place with wire loops. Even though the stabilizer is adjustable in flight, the right elevator (shown here) has a perforated T.E. trim tab, adjustable only on the ground, similar to that found on the rudder.

Zeke 32 (Hamp)

A two-spar full-cantilever type, the Zeke stabilizer attaches to the tubes running through the fuselage formers by two shear taper pins on each spar. These tubes extend out 1⅞ in. from the monocoque to the bolt centers, the gap being covered by a fillet extending back to the tail cone.

Inboard stabilizer ribs (1) are of built-up truss type; the other seven are conventional stamped, flanged aluminum alloy with lightening holes. Two spanwise channel stringers are used, one extending out to the tip, the other ending at the fifth rib. The leading edge has intercostals between each of

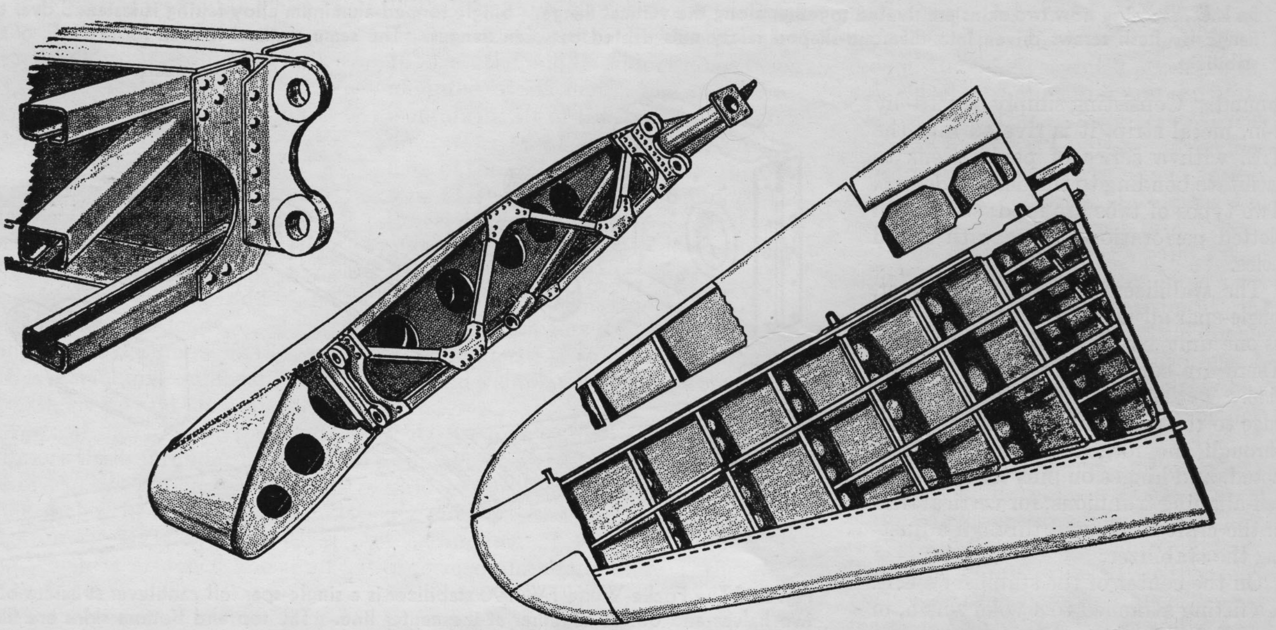


Fig. 1. Stabilizer inboard rib and fuselage attaching fittings are shown in the detail sketch (top left), with a profile view (center) showing how the L.E. of the stabilizer is attached top and bottom by piano hinges. The elevator torque tube is shown just aft of the rear spar. The plan view (right) with a portion of the skin removed, shows the rib and stringer construction. Stabilizer T.E. skin is crimped to form hoods over the elevator L.E., as is done on the vertical fin.

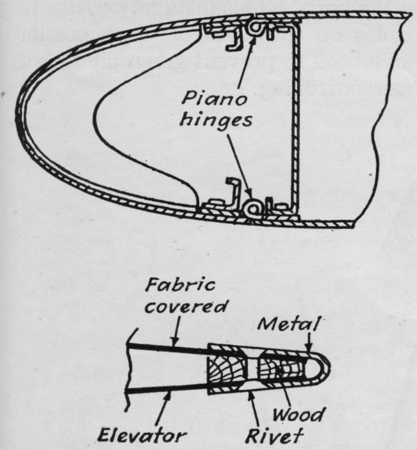


Fig. 2. Cross section of the stabilizer L.E. showing the method of attachment to the spar by piano hinges. The detail at the bottom shows the construction of the T.E. of the elevator, illustrating the use of wood for added stiffness with minimum weight.

the ribs. This section is attached to the front spar by top and bottom piano hinges (2).

The skin is all flush-riveted, the gauge for the L.E. being .025; remainder, .018. It extends aft of the rear spar, and both top and bottom surfaces are crimped to form hoods over the elevators.

Conventional fabric-covered elevators are single spar with stamped, flanged ribs having lightening holes ¾ in. apart. The fabric is sewed on in the old style, rather than being attached by metal clips or wire. The spar root forms a box into which the torque tube is riveted. This tube in turn is butt-bolted to a torque tube mounted in the aft fuselage with the mass balance attached to it.

One craft examined had stop cables attached to the horn, possibly to prevent green pilots from overcontrolling. Elevators have three self-aligning ball-bearing attachments for connection with the stabilizer.

The elevators are the only control surfaces having trim tabs adjustable in the air. Operation of the tabs is by a vernier drum in the cockpit from which cables lead to a gear box mounted on a former. A short length of chain gives positive drive to the gears, and a crossed cable carries motion to the right-hand tab. Universal joints are installed just behind the gear boxes, with torque tubes from there to another pair of universal joints just ahead of the elevator torque tubes (3). A small crank turning in a slot in the tubular tab spar serves to change its angle (4).

More than one Japanese pilot possibly had trouble with his tabs, for no provision has been made to prevent fouling of the crossed cable turnbuckles, short little gadgets which apparently are necessary to keep the cables tight enough to give the necessary drive.

The vertical fin is built integrally with the fuselage except for the 10-in. deep L.E., which can be detached by removing wires from the piano hinges on either side. Backed by intercostals and ribs 5¼ in. apart, the skin on the L.E. is .025 gauge; that along the sides is .016 and, as in the case of the stabilizer, the skin is carried aft of the rear spar and crimped on either side to form a horn over the rudder. Of two-spar construction, the fin has four stamped, flanged horizontal ribs.

Conventional design is also followed in the fabric-covered rudder (5), except that the small metal trim tab is adjustable only on the ground. The single spar is stamped, flanged and with lightening holes, as are the ribs. The aerodynamic balance horn, of some 46 sq

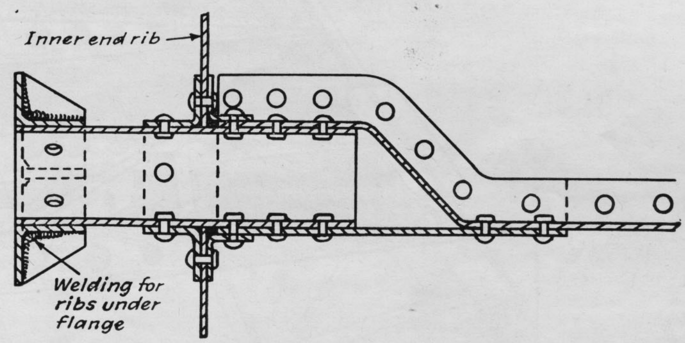


Fig. 3. Elevator torque-tube detail, showing the method of attaching the tube to the elevator spar.

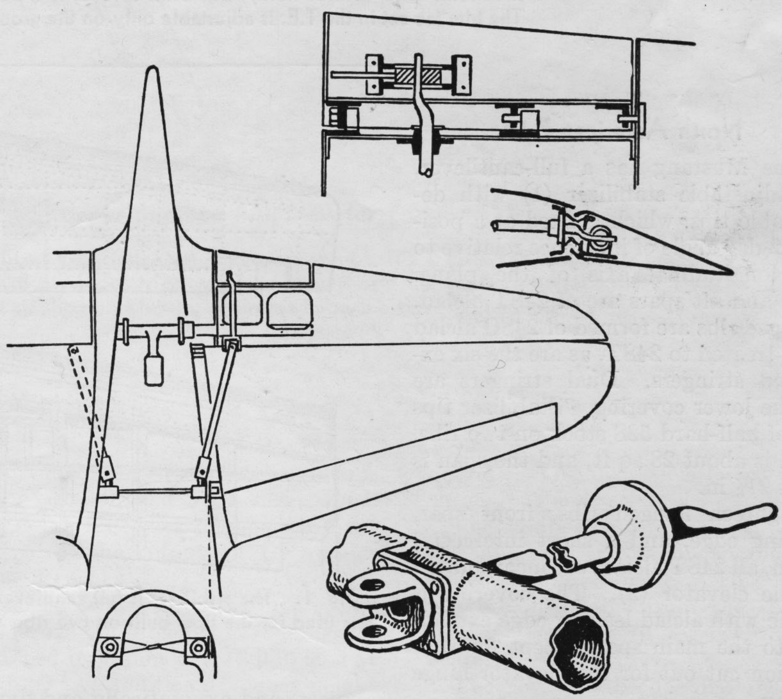


Fig. 4. Details of the elevator trim tab controls, cable-operated from fuselage. The universal joints, shown in the plan view, are interconnected by cable as shown in detail (lower left). The tabs are operated by small cranks engaging a sliding bar encased in a slotted tube attached to the tab by angle brackets at each end.

in., is set at the top, fitting into a cutout in the fin. Three hinge points have self-aligning ball bearings, and the torque tube mounted on the bottom end is located within the fuselage.

The rudder horn has a 5-in. spread, and some Hamps have had wooden stopblocks installed in the hinge fitting at the horn. This installation, like the cables on the elevator, may possibly have been to prevent green pilots from overcontrolling.

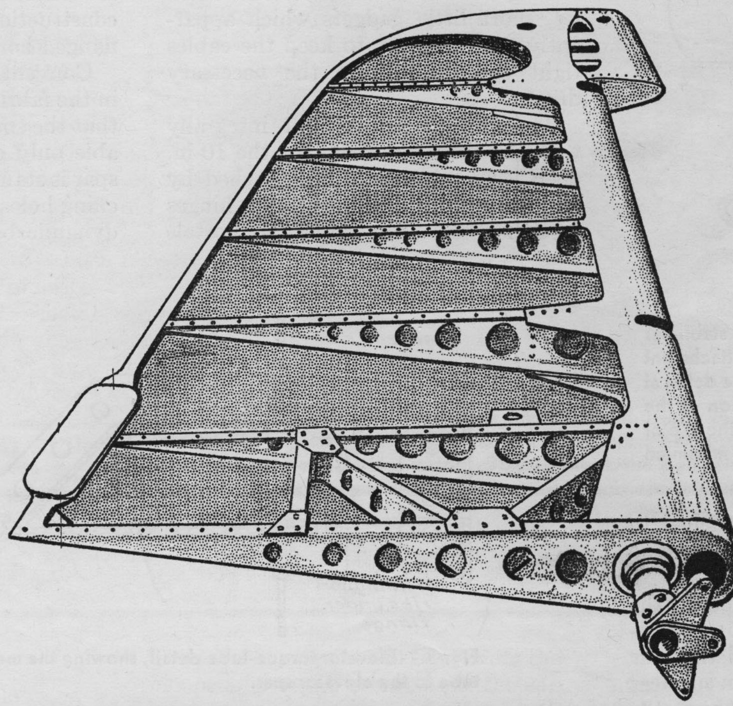


Fig. 5. Rudder with one side of the fabric covering removed to show rib construction. The control horn, with 5-in. spread, is welded to the torque tube. The trim tab set in the T.E. is adjustable only on the ground.

North American P-51

The Mustang has a full-cantilever, nonadjustable stabilizer (1) with detachable tips, which is fixed at a positive 2-deg angle of incidence relative to the longitudinal axis of the plane. Fore and aft spars are of 24ST alclad. Flanged ribs are formed of 24SO alclad heat-treated to 24ST, as are the six extruded stringers. Dual stringers are on the lower covering. Stabilizer tips are of half-hard 52S stock on two ribs. Area is about 28 sq ft, and the span is 13 ft 2⅛ in.

Eighteen flanged ribs, front spar, trailing edge, and a short intercostal beam, all 24ST alclad, are incorporated in the elevator (2). The covering is fabric with alclad leading edge extending to the main spar, except for that portion cut out for the elevator hinge fitting.

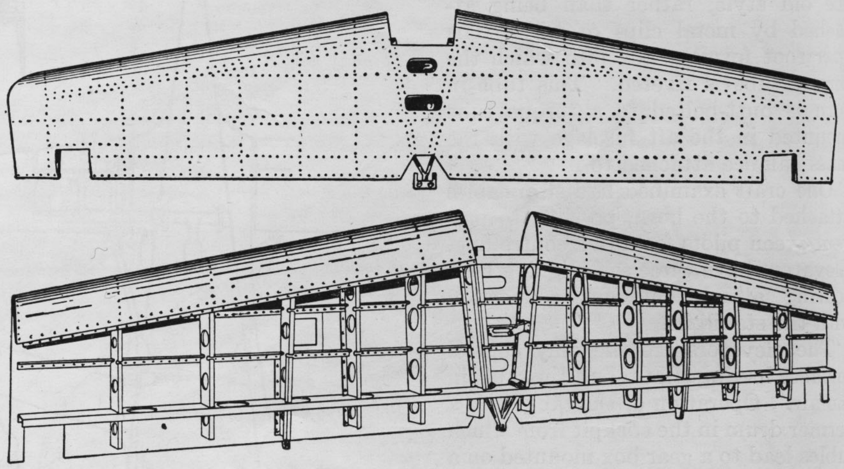


Fig. 1. The stabilizer is full cantilever type with alclad frame and covering. Half-hard 52S is used for the tips, built on two ribs.

The right and left elevators are interchangeable, are fastened to the stabilizer with five sealed ball-bearing hinges, and are statically and dynamically balanced. Static balance is by a 13¼-lb lead weight attached to the outboard end of the L.E.

The total elevator area is about 13 sq ft, and angular movement by the control stick is 30 deg up and 20 deg down. Each elevator has an adjust-

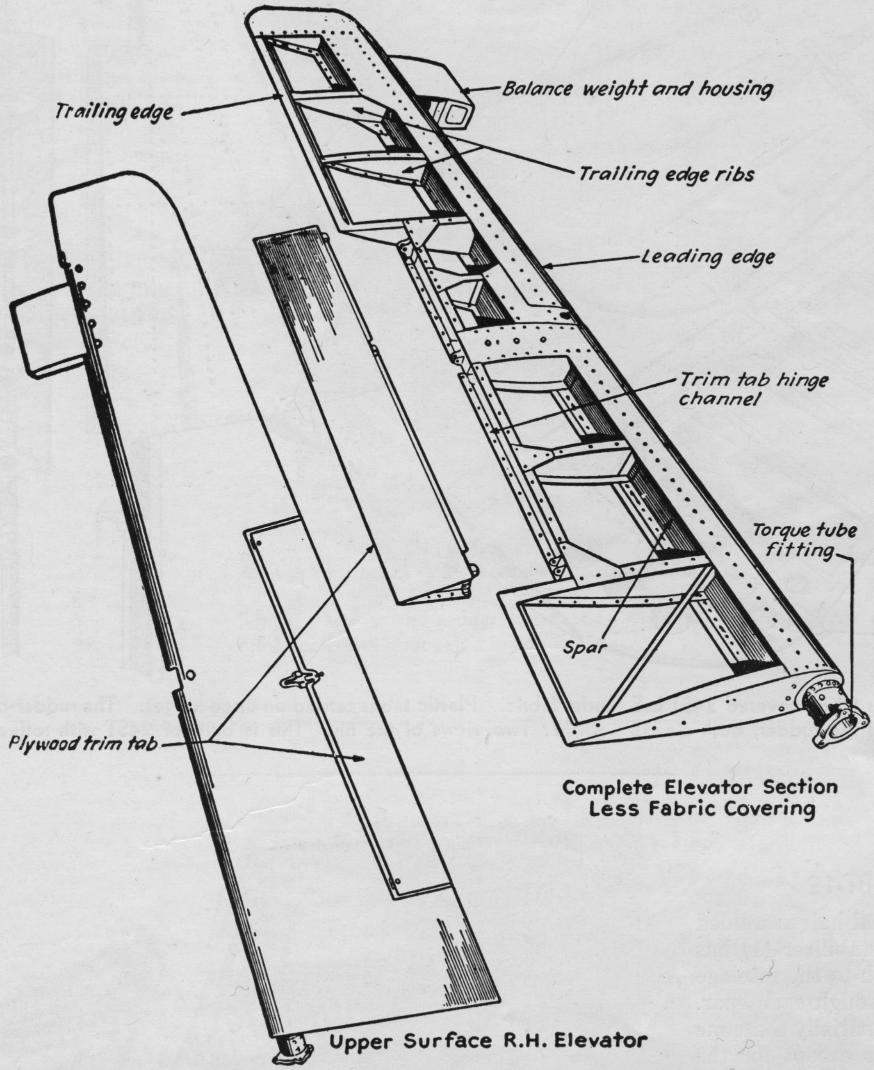


Fig. 2. The elevator is built of 24ST frame with fabric covering. The L.E. is 24ST under fabric. The trim tab, made of plywood, is operated by a horn near the center. Balance weights are concealed in the stabilizer. Elevator control is through a three-bolt coupling at the inside end.

able trim tab approximately $4\frac{11}{32}$ by $32\frac{1}{16}$ in.

Having front and rear spars of 24ST alclad, the ribs of the fin are covered with 24ST alclad sheet. The tip is on two ribs, and the skin is stiffened spanwise by light rolled stringers. The area of the fin is 9.61 sq ft, and it is set 1 deg to the left of the center line of the rear beam.

The rudder (3) consists of spar, 20 flanged alclad ribs, V T.E., and a short beam in front of the trim tab, which is fabric-covered, and 24ST sheet which covers the L.E. back to the main spar, except for the cutout for the rudder hinge fitting.

Hinged to the fin with three sealed ball bearings, the rudder is dynamically balanced by means of a 16.6-lb lead at the top. An additional balance weight at the bottom of the L.E. reduces static unbalance. Area is 10.4 sq ft. Angular movement is 30 deg each side of neutral. The operation is by pedals through cables.

Phenol-fiber trim tabs on the elevators and rudder are hinged by three sealed needle bearings. The rudder tab is controllable from the cockpit. Angular travel is 10 deg each side of center.

The elevator tabs, operated by a control wheel on the left of the cockpit, have angular travel 10 deg up and 25 deg down, limited by stops on the cable.

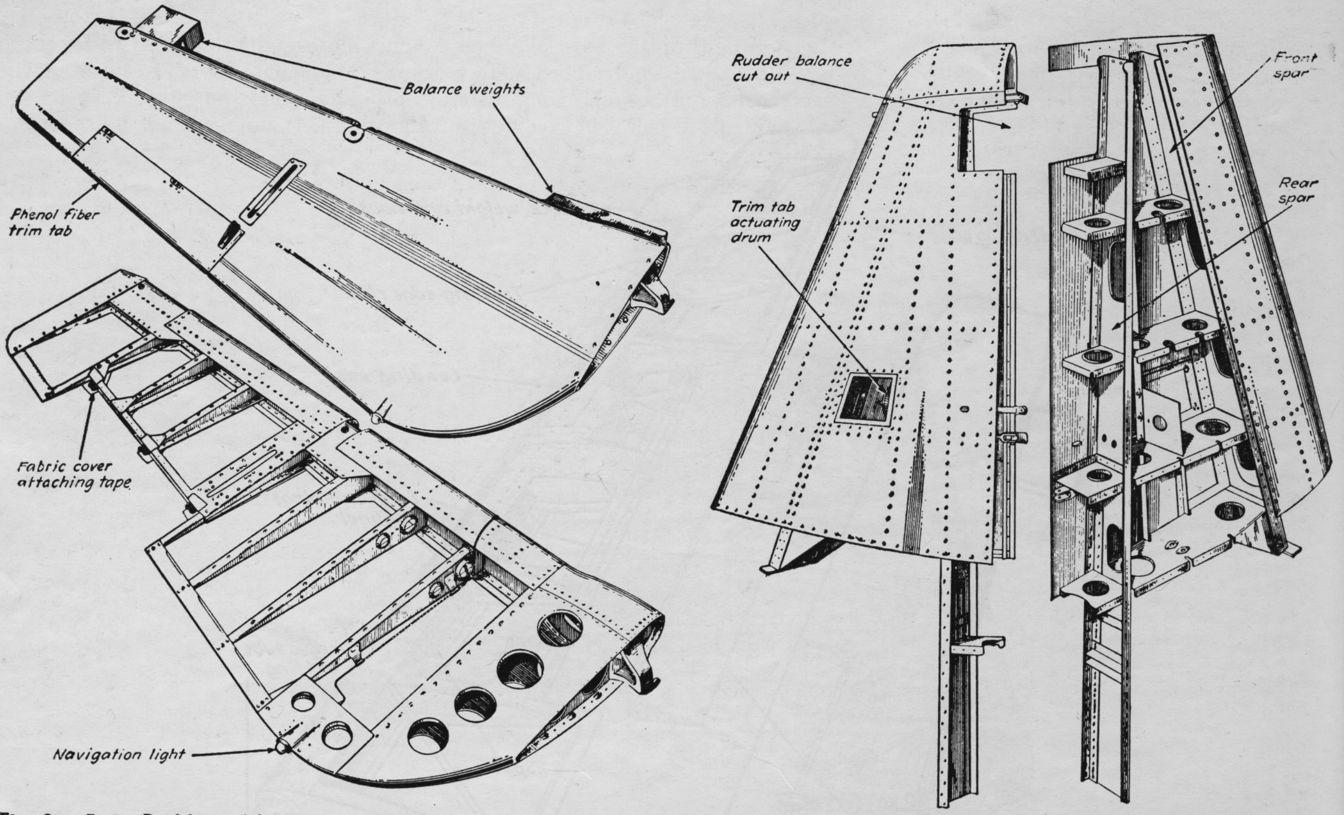


Fig. 3. *Left:* **Rudder is fabric-covered 24ST L.E. under fabric. Plastic tab is carried on three hinges. The rudder-operating horn is a forging (shown at the bottom of the rudder, both views).** *Right:* **Two views of the fin. This is built of 24ST with rolled stringers and is covered with alclad sheet.**

Fleetwings BT-12

Built in two identical halves welded together, the BT-12 stabilizer (1) has two spars which attach to the fuselage by four bolts, two through each spar. The construction is essentially the same as in the outer wings except for the stabilizer tips which are annealed stainless steel formed under a drop hammer.

Elevator hinge brackets are of routed dural plate, bolted to the stabilizer by two bolts each. They are equipped with self-aligning ball bearings, and hinge pins are standard ¼-in. clevis bolts.

The elevators, of single torque box construction, have stamped trailing ribs and fabric covering. A different method—conventional nonflush lacing—is used for covering the tail surfaces from that used on the wings. Trailing-edge ribs are rubber press-formed, annealed, stainless, reinforced where required, with full-hard stainless angles under the flanges. The trim tabs are of the same type construction as the elevators.

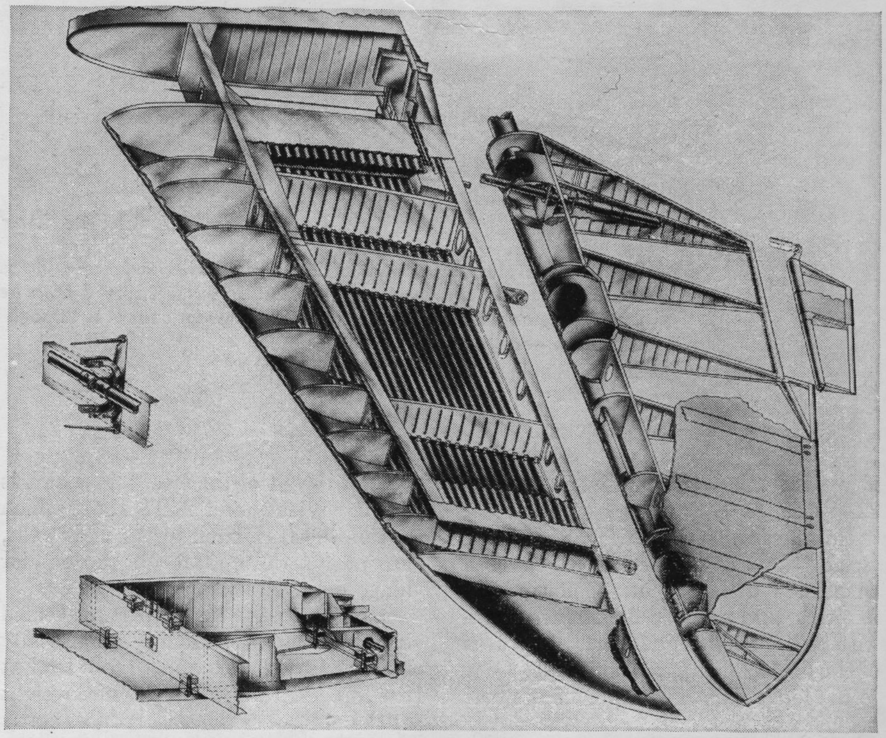


Fig. 1. The stabilizer has stainless-steel two-spar construction with corrugated ribs and plain nose formers. The elevator has D-section spar and pressed stainless-steel ribs, fabric-covered.

Four bolts hold the fin to the tail section (2), two from the front lower fin spar to the front stabilizer spar, and two from the rear spar to the tail post.

The fin ribs are stamped stainless; the covering is stainless corrugation and skin. Fairing between fin and stabilizer and fuselage is dural sheet fastened by brazier-head screws and channel-type stop nuts. Rudder hinge brackets are also of dural, two being fastened to the rear fin spar and one to the tail post.

The rudder construction, similar to the elevators, has stamped ribs, stainless leading edge, and fabric covering. The trim tab is similarly constructed.

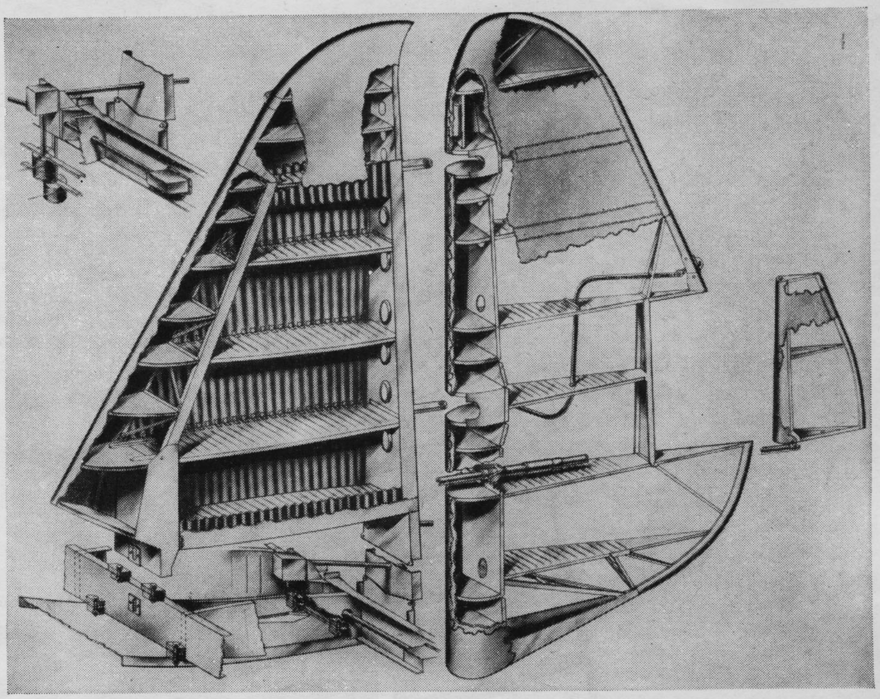


Fig. 2. The fin and rudder construction is similar to the stabilizer and elevator. The fin is reinforced with corrugated inside skin.

Republic P-47N

The P-47N tail is constructed of an aluminum alloy frame and a riveted metal skin (2). Fillets are installed at the roots of the fin and stabilizers.

Rudder and rudder trim tab cables run through the front stabilizer spar on which is bolted a built-up fitting for attaching the fin spar (1).

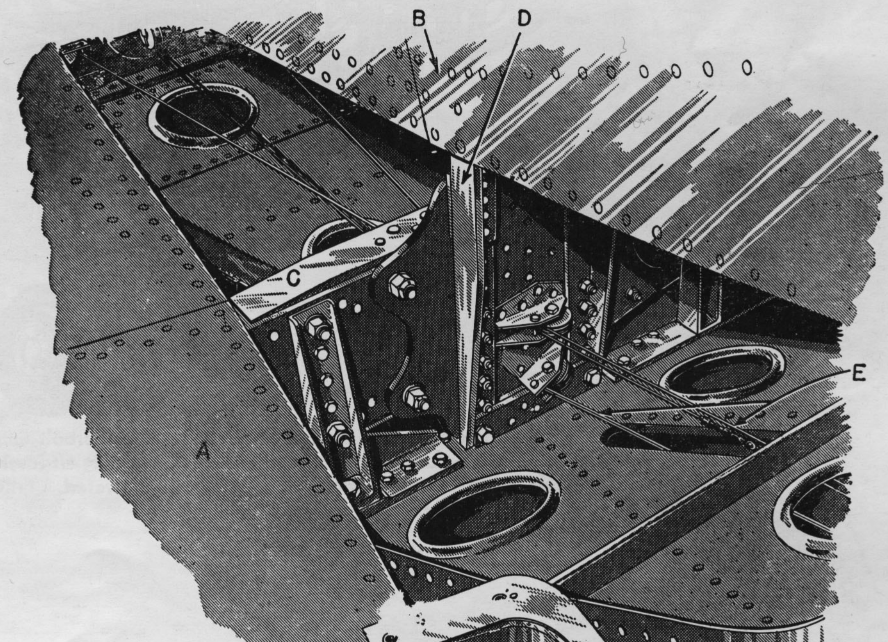


Fig. 1. Fillet removed between stabilizer (*A*) and fin (*B*) of a P-47N to show the front stabilizer spar (*C*) and built-up fitting (*D*) for attaching the fin spar. Cables (*E*) lead to the rudder and rudder trim tab.

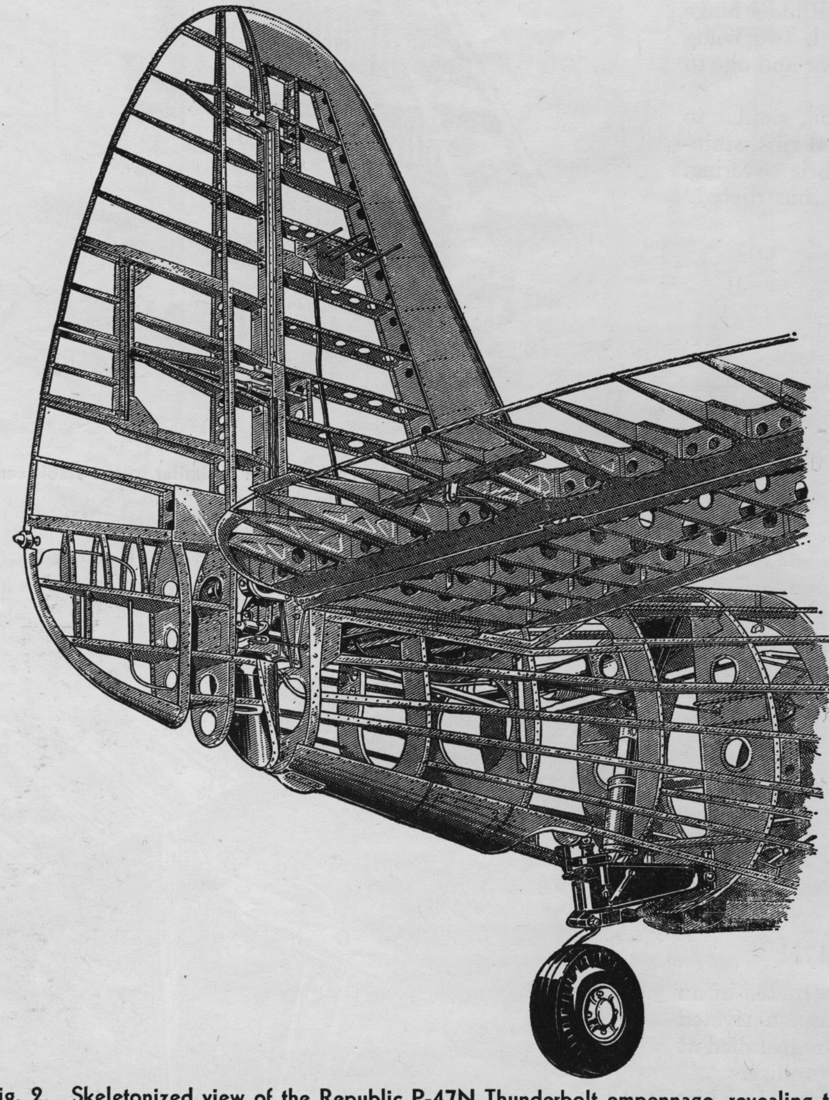


Fig. 2. Skeletonized view of the Republic P-47N Thunderbolt empennage, revealing the structure of fin and rudder, stabilizer, and elevator, including aft fuselage showing the installation of the retractable tail wheel. The metal skin is riveted. Fillets are provided at the roots of the fin and stabilizers.

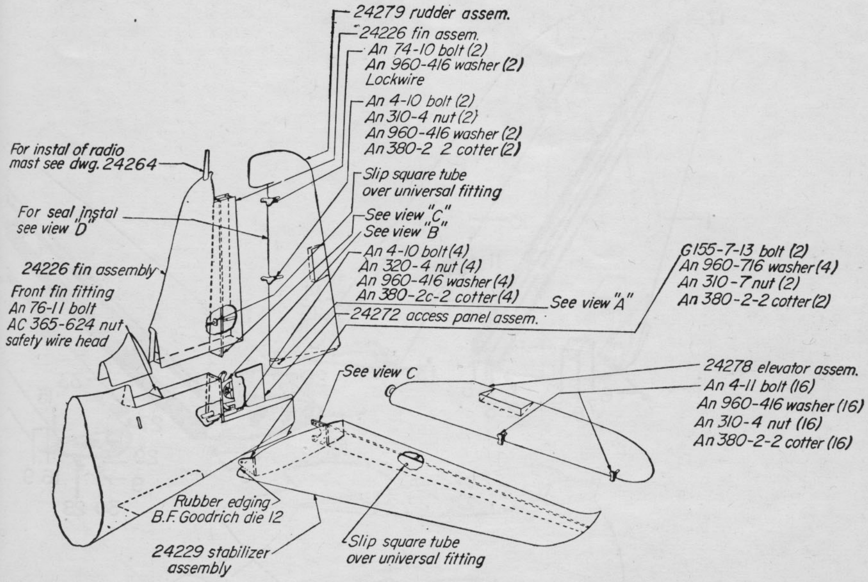


Fig. 1. Exploded view showing the major components of the Grumman F6F Hellcat empennage.

Grumman F6F

The rudder and elevators of the F6F are fabric-covered aluminum alloy structures, with elevators interchangeable, right and left. The fin has a single spar, stamped aluminum ribs, and flush-riveted metal skin which is reinforced at the trailing edge to form a recess into which the rudder is sealed with fairprene strips. There are six major components in addition to a fairing between the fin and the fuselage (1). The fin can be detached from the fuselage by the removal of five bolts (2).

The stabilizers have single-shear webbed spars to which are riveted stamped aluminum ribs. The stabilizer is attached to the fuselage at two points. The tip is quickly removable (3).

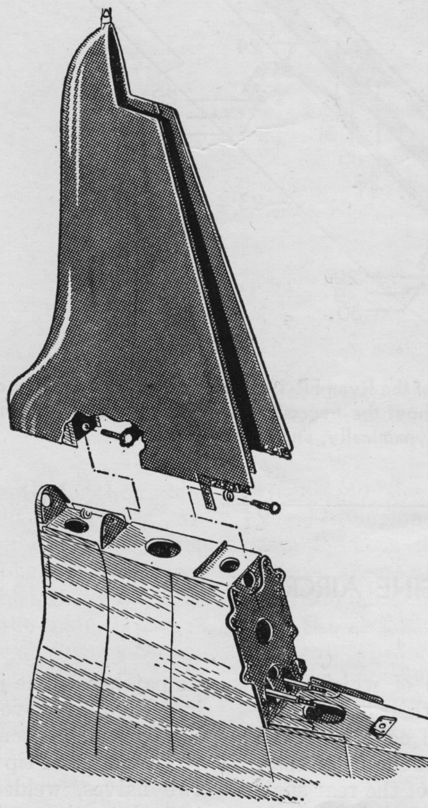


Fig. 2. The vertical fin of a Grumman F6F can be removed from the aft fuselage by removing five bolts; four near the T.E. and one near the front.

Fig. 3. The Grumman F6F Hellcat stabilizer unit is built of stamped ribs riveted to a single-shear webbed beam and attaches to the fuselage at two points. The juncture with the fuselage is sealed with rubber edging. The tip is quickly removable.

Ryan FR-1

The empennage of the FR-1 is constructed as a complete subassembly, removable without the necessity for rigging controls (1). There are six major components comprising the tail: two horizontal stabilizer units, two elevators, a fin, and the rudder.

Both rudder and elevators are balanced statically, dynamically, and aerodynamically.

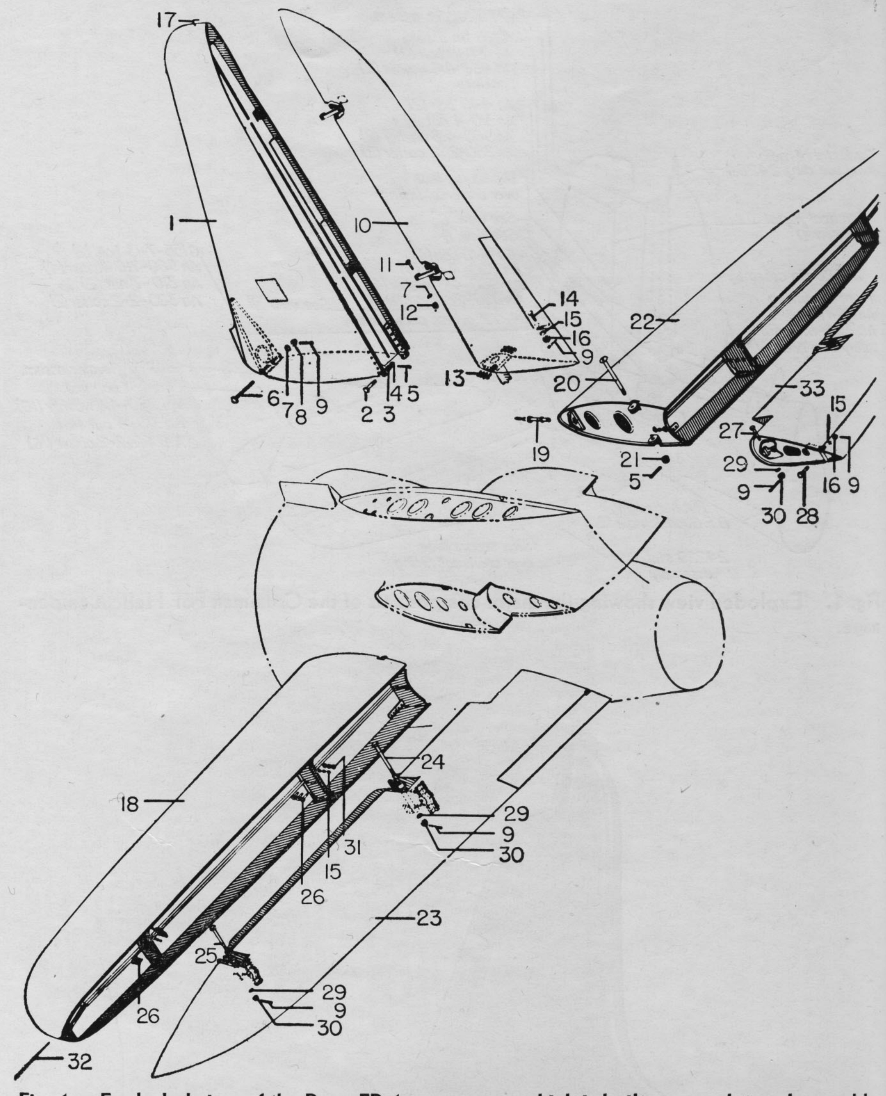


Fig. 1. Exploded view of the Ryan FR-1 empennage which is built as complete subassembly that can be removed without the necessity for rigging controls. Both rudder and elevators are balanced statically, dynamically, and aerodynamically.

PART 2. TWIN-ENGINE AIRCRAFT

Messerschmitt Me-262

The end of the Me-262 tail cone is a stamped, flanged aluminum channel member which serves also as the bottom of the rear fin spar and rudder post.

Connecting the tops of these two spars is a horizontal stamped, flanged channel member upon which the stabilizer is mounted. In production, the stabilizer must be installed before the fin and rudder are put in place (1).

Then the fin, spars of which have steel plates riveted to their lower ends, is attached to the tail cone by seven bolts along each side of the front spar, and four on each side of the rear spar.

In construction, the fin is built up in two halves, divided on the vertical plane of the fuselage axis. The halves are then bolted together along the spar line through access holes in the skin. These holes—about 1 in. in diameter—are then covered with small doped-fabric patches. The joint along the leading edge is covered with plywood fairing which is screwed in place.

The rounded tip of the fin is built in two halves, welded together and attached to the main body with flush screws. A single-sheet, deep-drawn aluminum fairing is fastened by 41 flush screws to the base of the fin and fuselage top.

The rudder chord is narrow, being only 20¼ in. at the widest point, but

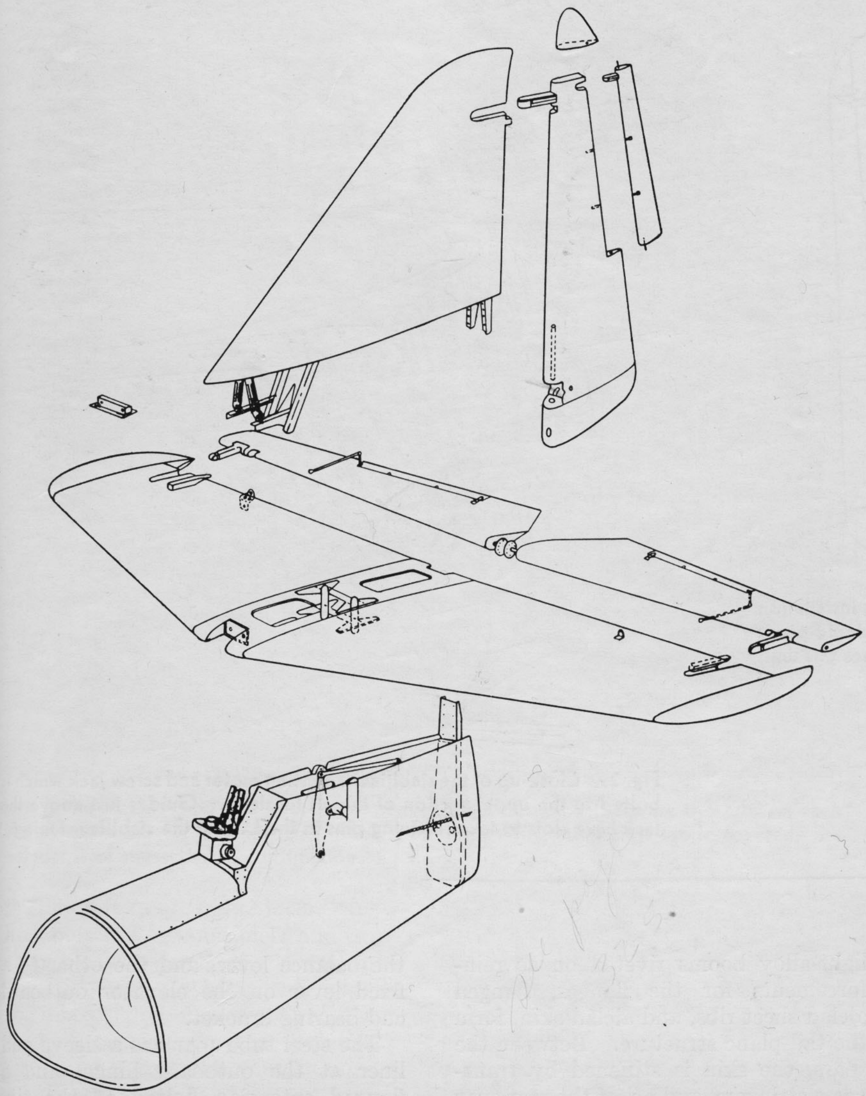


Fig. 1. Exploded view showing the construction of the empennage. In assembling the Me-262, the stabilizer is put in place, then the vertical fin is bolted to the aft fuselage section.

there is plenty of depth, for the rudder has an over-all height of 6 ft 11 in., extending from the top of the fin to the bottom of the tail cone. A small tip is screwed to the top just above the large mass balance, and the main section of the unit follows conventional constructional practice.

The spar is of D section, with the curved part fitting closely inside the fin trailing edge. Conventional stamped, flanged aluminum ribs with lightening holes extend back to the T.E., where the skin surfaces are crimped together and riveted with $\frac{3}{8}$-in. ordinary-type roundhead rivets.

The fore part of bottom portion of the rudder, beneath the lower hinge, is comprised of two formed sheets flush-riveted to the spar and lowest rib. The aft portion, containing the formation light, is made up of two small formed sheets attached by flat screws.

Although quite deep, the rudder has but two hinges, both typical self-aligning ball-bearing units. The top bearing is set just beneath the mass balance; the lower at the bottom rib, where the push-pull controls also attach.

The combination servo and trim tab, oddly enough, has four hinges and, comparing its construction with other parts of the plane, gave evidence of having come from a different shop. It, too, has a mass balance, set right under the top self-aligning ball-bearing hinge. The two middle hinges are small metal blocks with vertical pins holding them to the tabs and yokes attaching to the rudder false spar, giving a universal-joint effect. The lower hinge is a vertical pin extending up from a rudder rib. The T.E. of the tab is formed by crimping together the skins, round which a strip is folded and flush-riveted. It is $36\frac{3}{4}$ in. deep, with a $4\frac{7}{16}$-in. chord at top and 6 in. at bottom.

The Me-262 all-metal stabilizer is adjustable, the incidence being changed by a small electric motor operating a screw jack mounted inside the fin fairing on the front face of the frame (2) to which the vertical fin is bolted. This unit (3) is very similar to that on the FW-190.

The stabilizer, spanning 12 ft 4 in., is built in top and bottom halves, which are bolted together through access holes that are later fabric-covered. A built-up I-beam spar is located 24 in. from the L.E. and $18\frac{3}{4}$ in. ahead of the T.E. It is attached to the fuselage by through bolts to two forged fittings set in ball bearings at the axis of the angle adjustment. The L.E. has a 25-deg sweepback.

All-metal elevators follow conventional design practice, with a stamped, flanged spar, rounded metal L.E. shrouded into the stabilizer T.E., and stamped, flanged ribs. The T.E. are formed simply by crimping the skins together and riveting, with ordinary rivets as in the case of the rudder.

The outboard hinges are self-aligning ball-bearing units, set just outside the large mass balances at the tips, while the center units are of similar type set just beneath the vertical fin.

Both elevators have 27- by $2\frac{1}{2}$-in. mass-balanced trim tabs set near the inboard end. These tabs apparently were designed as interchangeable servo units, for a small arm at the outboard end extends up from the right one and down from the left, and captured German documents show an anchoring arm designed into the stabilizer T.E. However, operational experience or Allied bombing made completion of this plan impossible, for the tab arms were not connected to the stabilizer and, in fact, the tabs had been riveted into immobility by small gusset plates at each end. Nevertheless, each tab had four hinges, with ball-bearing units at each end and pins through yokes for the two in the middle. As in the case with the rudder trim tab, T.E. of the tabs are nicely flush-riveted.

One-piece pressed-aluminum stabi-

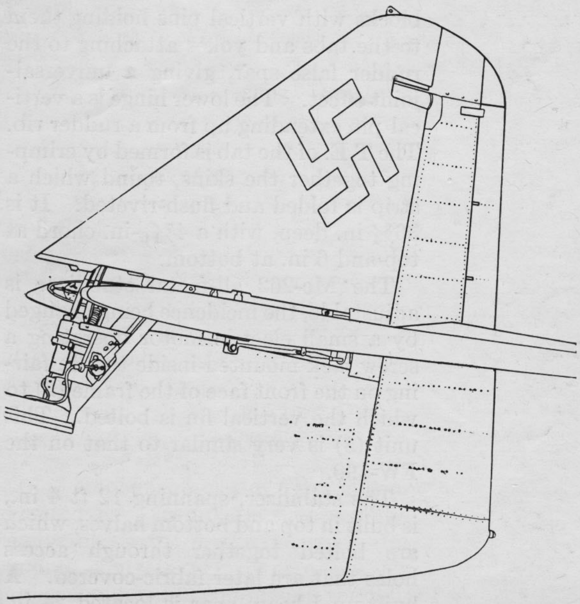


Fig. 2. Over-all view of the empennage, showing installation of the stabilizer and its adjusting mechanism. A single-piece drawn aluminum fairing, held by 41 screws, encloses this unit.

lizer fillets are held in place by a L.E. pin which moves up and down between greased strips riveted to metal brackets just above the adjusting jack, and by screws—one top and bottom—10 in. aft of the stabilizer spar.

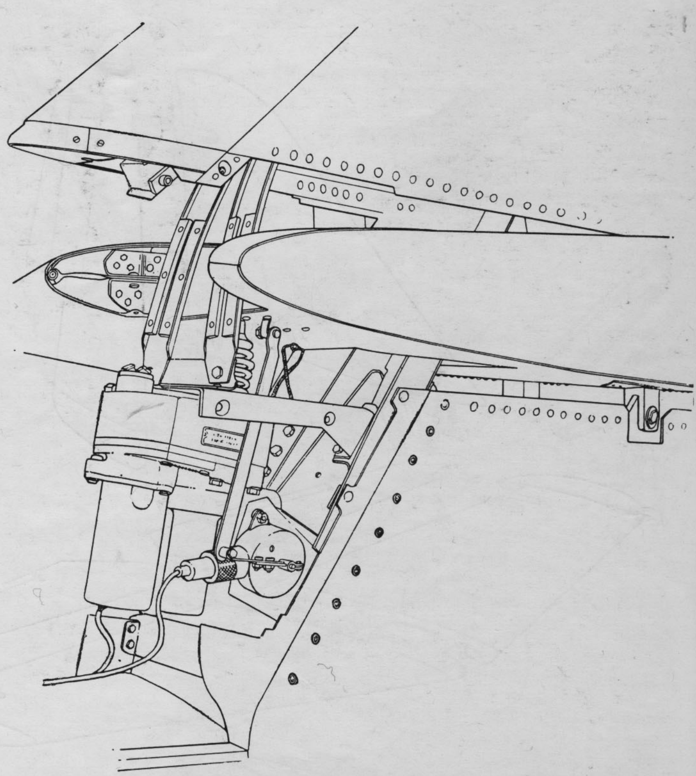


Fig. 3. Close-up of the stabilizer adjusting motor and screw jack which is bolted to the upper section of the aft fuselage. Guides just above the jack have slots to take retaining pins in the L.E. of the stabilizer fairing.

Bristol Beaufighter

Comprising a cantilever stabilizer and fin, elevators, and a rudder, all-metal construction is used for the stabilizer and fin, while the elevators and rudder have a fabric-covered metal framework in the Beaufighter's tail unit. Early models of the plane have no dihedral in the stabilizer; in later models the stabilizer has a pronounced dihedral of 12 deg.

Rudder and elevators have inset trim tabs, and each elevator has a balance tab. Stabilizer attachment fittings, extending to the upper surface, also serve as fin attachment points. Both fin and stabilizer are faired, at the juncture with the rear frame, by fillets secured by wood screws to wooden fairing strips on the fin and frame.

The stabilizer in early models was built in one piece; in later planes it is built in three pieces, a small center and two outer panels. The outer panels are riveted to the center section. Construction of both types is similar. Two alclad channel spars, with extruded light-alloy booms riveted on as reinforcements for the flanges, flanged alclad sheet ribs, and alclad skin, form the tail plane structure. Between the spars, the skin is stiffened by transverse stringers, and aft of the rear spar inboard of the cutaways for the elevator balance portions, a false spar is fitted. On either side of the stabilizer center line, a steel interspar tube between the stabilizer-to-fuselage attachment fittings reinforces the structure.

An inspection door is in the upper surface. Elevator hinge bearings are on two brackets, one secured to the rear spar and false spar on the stabilizer center line, and one on each outer panel inboard of the elevator cutaways. The stabilizer tip edge is of wood, secured by wood screws to the skin overlap.

The fabric-covered elevators are built in separate halves, having a tubular spar, alclad ribs and nosing, and a trailing edge of oval tube (1). A trim tab, controlled by the pilot, is in the inboard T.E. of each elevator. A balance tab in the T.E. is operated by a rod, one end of which is attached to the balance lever, and the other to a fixed lever on the elevator outboard end bearing bracket.

The steel tube spar has a sleeve and liner at the outboard hinge, and a flanged extension bolted at the tip. The ribs, of flanged alclad with flanged lightening holes, are secured to the spar by collars fastened by Chobert rivets. The eyelets for the fabric are in the flanges.

An oval steel tube forms the T.E. outboard of the trim tab. From the inboard end to the balance portion, the nosing is of alclad sheet riveted to the ribs. The balance portion is covered with alclad, with a wooden nose fillet held by wood screws.

Mass-balance weights are secured to the nose. A fairing of aluminum-manganese sheet is fitted at the inboard end of each elevator, aft of the alclad nosing. Fabric covering extends around both the balance portion and the nosing.

The elevator horn is bolted to a socket on the inboard end of the spar. The pin for the final connecting tube from the elevator control passes through

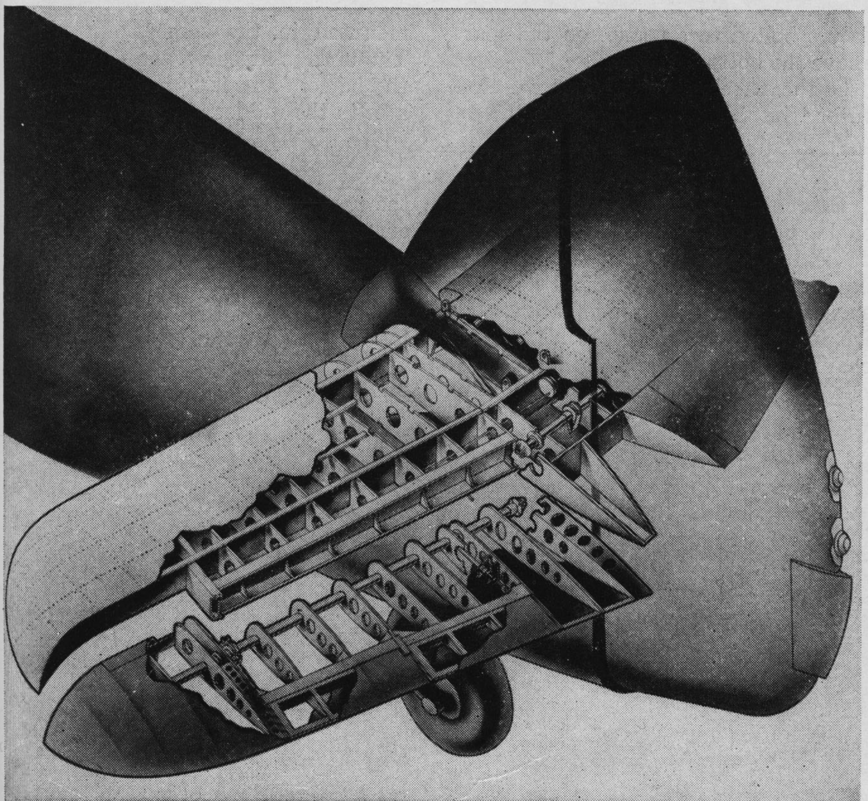


Fig. 1. The elevator and stabilizer are of conventional design. There are two tabs on each elevator, outboard for balance and inboard for trim. The elevator is fabric-covered; the remainder is of stressed-skin construction.

A removable panel, secured by set-screws, covers the gap between the bottom rear channel and the sternpost. This is a mahogany-filling piece inside the top rear channel member, and there is a spruce strip for attachment of the fairing fillets on each side of the bottom rib. The steel aerial attachment bracket is riveted to the apex of the fin.

Rudder construction is similar to the above. An inset trim tab is controlled by the pilot. The spar is a light-alloy tube with a flattened extension near the tip. The ribs and their attachments are similar to those of the elevator. Above the trim tab and up to the top of the foremost point of the balance portion, the T.E. is a mild steel tube, but below the trim tab it is light alloy. The nosing and balance portion are similar to those of the elevator; mass-balance weights are bolted under the nose fillets. A fairing of aluminum-manganese is secured to the rudder bottom by Chobert rivets. In the T.E. are two tail lamps, with cables running in conduits along a rib and through a door in the nosing.

Fabric covering extends right around the nosing and balance portion. Inspection doors are at the left side at mass-balance weights and trim tab

both the left and right levers and (with a bolt and distance piece and two packing blocks between the levers) interconnects both elevators. A spigot at the inboard end of each spar centers in a ball bearing on the stabilizer bracket and forms the center hinge. The outboard hinge has two split bearings in which the spar rotates.

Both trim tabs, which are quickly detachable and which are fitted with mild steel hinge points at the spindle ends, are constructed of a tubular light-alloy spar, alclad ribs and skin, and an oval tube T.E.

The fin has front and rear posts and a rear member of channel section. Alclad is used for the above as well as for ribs and skin, but the nosing is aluminum-manganese sheet.

The front and rear posts are reinforced at their lower ends to form box sections to which the steel-bushed fin attachment lugs are bolted. The front lugs are bolted directly to the stabilizer front spar, while the rear lugs are connected through links to the rear stabilizer fittings. A rearward extension of the second rib from the fin base is bolted to the rear post.

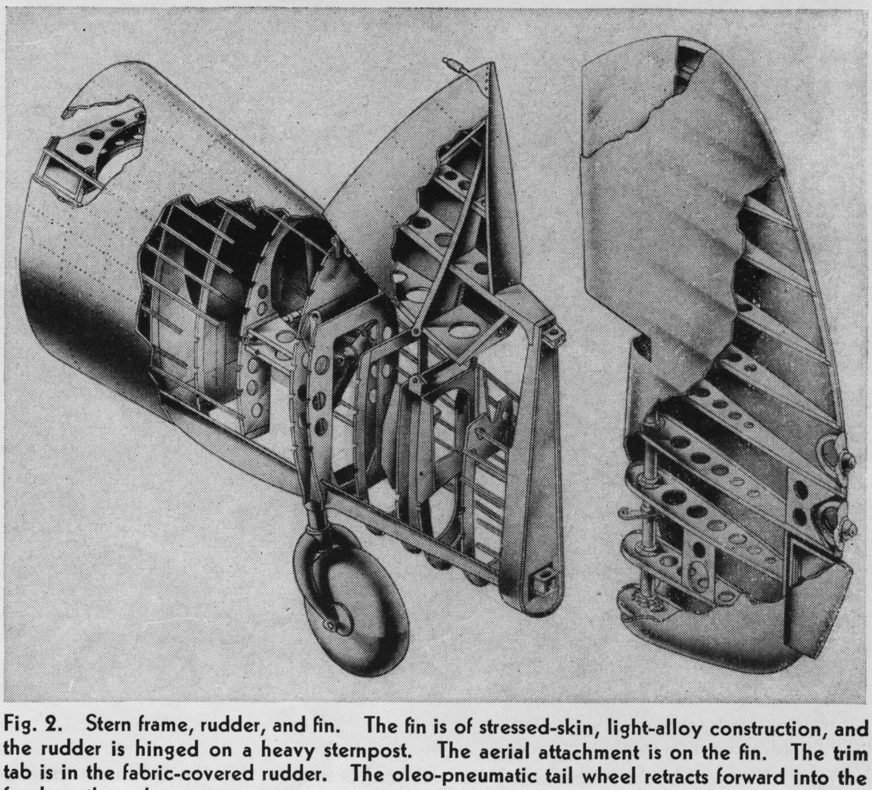


Fig. 2. Stern frame, rudder, and fin. The fin is of stressed-skin, light-alloy construction, and the rudder is hinged on a heavy sternpost. The aerial attachment is on the fin. The trim tab is in the fabric-covered rudder. The oleo-pneumatic tail wheel retracts forward into the fuselage through a trap.

actuator, also on right side, at rudder horn. The rudder is hinged at two points by double split bearings bolted to the sternpost (2). The horn is in halves bolted to a socket on the spar above the bottom hinge.

Of the same construction as the elevator trim tab, the rudder trim tab is mounted in the same manner also. The horn is fitted on the right side at the bottom and is linked to the actuator in the rudder.

Fairchild C-82 Packet

The C-82 boom assembly, constructed in two sections, forward and aft, is about 440 in. long. Supporting the tail structure, the boom assembly houses the surface controls and tail anti-icing ducts.

Extending 334 in. from aft of the engine nacelle, the forward boom (1) is of semimonocoque construction utilizing skin, light hydro-pressed channel section frames fabricated in halves, and longitudinal bending members. The channel frames (four, exclusive of the mating frame), for the first 100 in. from the forward end, are doubled to form composite units back to back. Longitudinal bending members are 75ST hat sections varying from .025 to .064, with heavy gauges on top and bottom because of gust and tow loads.

There are twice as many longitudinal members starting at the forward end

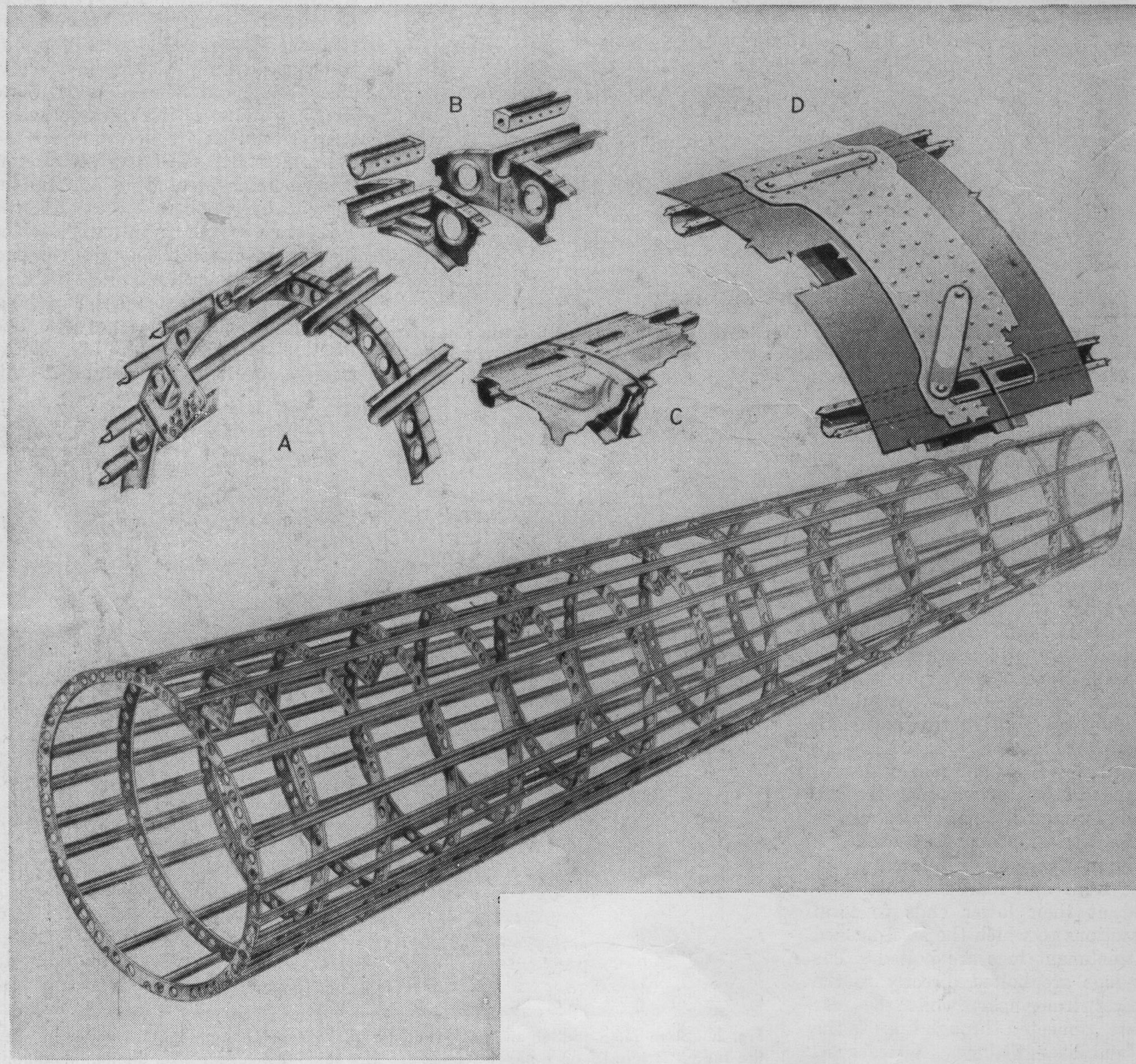


Fig. 1. Forward boom structure: (*A*) fairlead bracket support; (*B*) forward boom-to-aft boom attachment; (*C*) skin attachment at boom junction; (*D*) junction attachment cover strip having a cover plate for tension bolt inspection.

as those ending at the aft end (20 forward and 10 aft, with 10 terminating between).

Between the nacelle frame and forward boom and between the forward and aft booms, a splice of the bolted tension type employs forgings riveted to the stringers. A riveted skin splice makes the joint semipermanent.

Picking up vertical and horizontal tail loads, the aft boom (2) provides shelves to mount control pulleys and affords sufficient side bending and torsional stiffness for glider tow fittings at the extreme end. These features are accompanied by the use of heavy bulkheads, longitudinal members, and stressed skin.

Each of the forward two fitting-supporting bulkheads consists of back-to-back members having .040 webs and .064 flanges. Between webs is a ½-in. plate for supporting the main stabilizer and stabilizer tips. Bathtub-type tension fittings mounted in channels take the upper and lower fin loads.

The other frames in the tail cone sup-

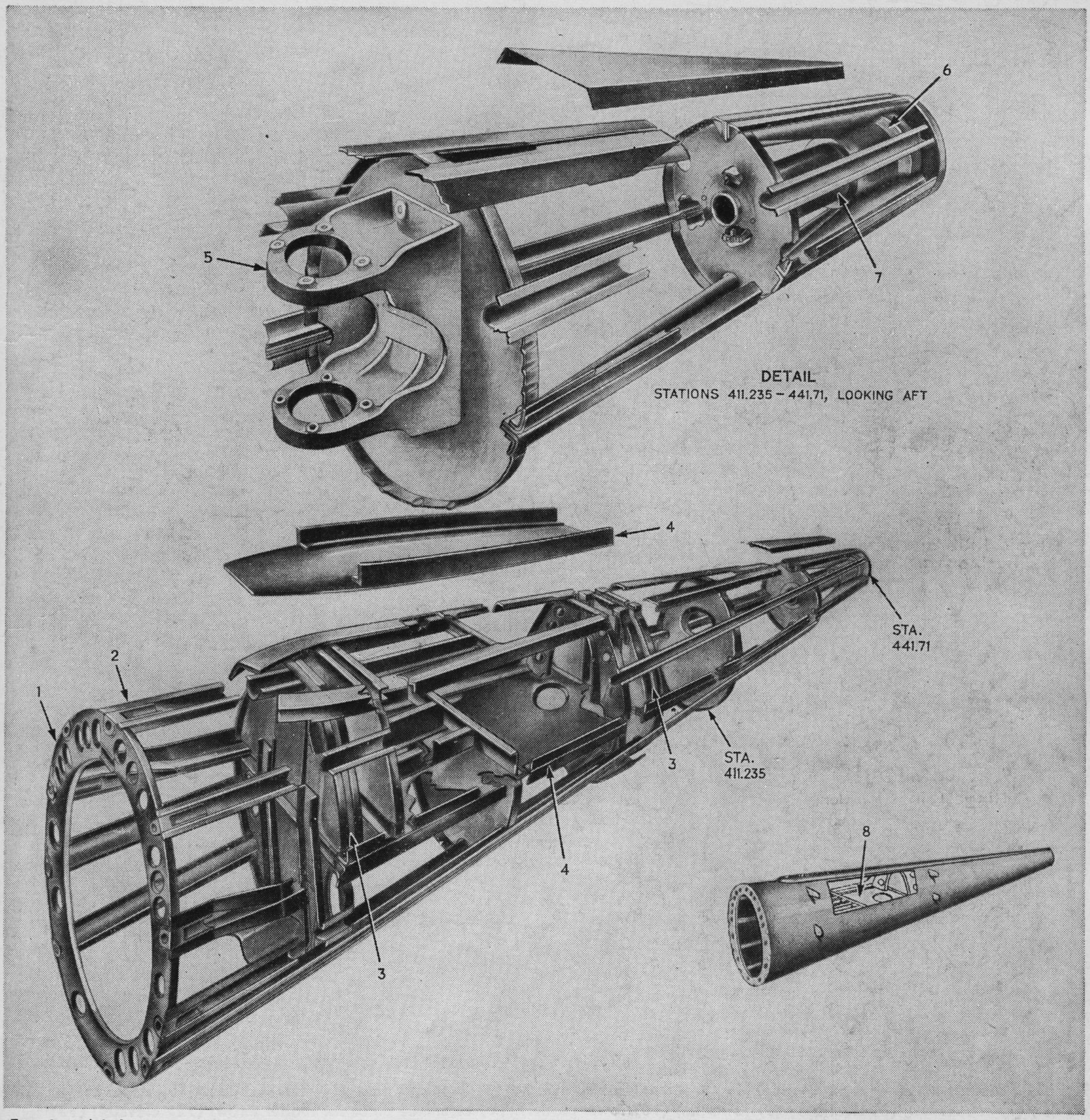


Fig. 2. Aft boom structure: (1) frame; (2) longitudinal member; (3) forward bulkhead; (4) shelf for control quadrant support; (5) rudder torque-tube bracket; (6) glider tow mechanism housing; (7) tow cartridge; (8) access opening to controls.

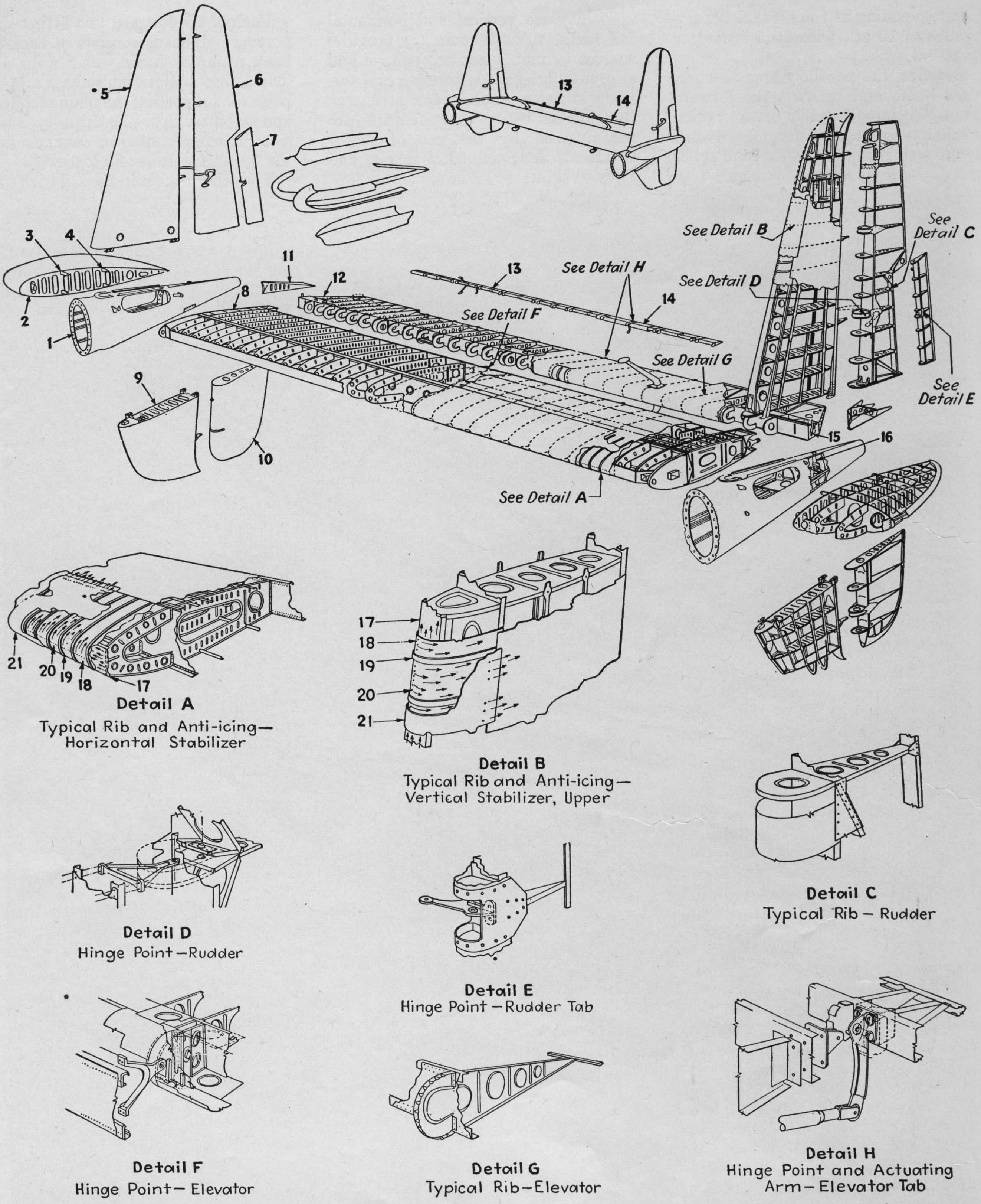


Fig. 3. Structural details of the tail group; (1) aft boom; (2) stabilizer tip; (3) front spar fitting; (4) rear spar fitting; (5) upper fin; (6) upper rudder; (7) rudder tab; (8) stabilizer; (9) lower fin; (10) lower rudder; (11) clearance piece for rudder throw; (12) elevator; (13) spring tab; (14) trim tab; (15) elevator horn; (16) rudder torque tube; (17) spanwise baffle; (18) inner skin; (19) spacer between inner and outer skins; (20) hot-air inlet; (21) outer skin.

port the rudder torque tube and the glider tow release mechanism.

An upper and lower shelf, each consisting of a web and angle caps, between the first two bulkheads, form two horizontal beams to provide strength for side bending. The shelves are spaced sufficiently to provide ample service accessibility for control quadrants supported between them.

Between the boom and elevator, on the inboard side, is a fixed elevator-shaped structure of width equal to the rudder throw, serving as a clearance space.

A tow-rope attachment at the end of each boom, together with a release mechanism selectively and electrically operated by a switch in the cockpit, provides for the towing of two 7,000-lb gliders, or one 18,000-lb glider.

Details of the tail group (3) are: Main stabilizer is of standard two-spar construction with ribs and skin. The front spar is approximately 15 in. deep with web thickness varying from .025 to .040 from the center to either end. Angle caps are .128 in the center and .064 at the ends. The distance from the front to the rear spar is about 41 in. The rear spar is about 12 in. deep with web gauge varying from .025 to .040. Lipped angle caps are .064 nested triple in the center and tapering off to one angle at the end. Hydro-pressed .025 interspar ribs and nose ribs are spaced about 10 in. on center. Over the interspar ribs are three longitudinal angle skin stiffeners.

Mounted externally, five elevator hinges are bolted to fittings at the hinge ribs which in turn are riveted to doublers inside. All hinges are designed for down loads, but only the end hinges are designed to take the side load and are braced accordingly.

Fabricated as one unit, the stabilizer, about 304 in. long and 64 in. wide, is attached to the boom by a single bolt at the front and rear spars, making it a pin-ended structure.

Of single spar construction having .032 web and single .040 angle cap top and bottom, the elevator has nose and trailing-edge ribs of minimum thickness. The elevator nose has a metal skin, and the entire surface is fabric-covered, similar to the aileron. Two tabs, one each side of the center line, are of the same construction also, one being a spring tab with special operating mechanism. Each tab is 6¾ in. wide and 93¾ in. long.

The upper and lower fins also are of two-spar construction with hydro-pressed ribs and all-metal skin. The spars are of standard web and angle type.

The upper and lower rudder is constructed like the elevator, with a fabric cover doped in place over the metal structure.

All fixed tail surfaces have anti-icing provisions, with duct in leading edge from which hot air flows into an .064 gap between the inner and outer skin, thence being exhausted to the outside near the front spar.

North American B-25 Mitchell

The B-25 empennage installation (1) is a twin-fin type containing a "stinger" gun position. The horizontal stabilizer (2) is a full cantilever stressed-skin structure of pressed ribs, spanwise stiffeners, and two spars. The front stabilizer spar is a web of .051 24ST alclad spliced to a heavier web of .064 material where it covers the fuselage. Beaded lightening holes and angle vertical members stiffen the web. The top and bottom capstrips are extruded angles riveted into place. The rear spar is substantially of the same construction except that the web is .051 throughout.

All ribs are made of .032 24ST alclad with flanges acting as caps and stiffening beads pressed in forming. Lightening holes and stringer cutouts also are provided. Stringers are extruded 24ST bulb angles and formed J sections. The stabilizer skin is .025 and .032 24ST alclad riveted to the framework.

The vertical stabilizers (3) are similar in structure and are attached to the horizontal stabilizer with standard AN bolts at the front- and rear-spar junction point.

Both elevator and rudder spars are formed of .040 24ST alclad with ⅞-in.

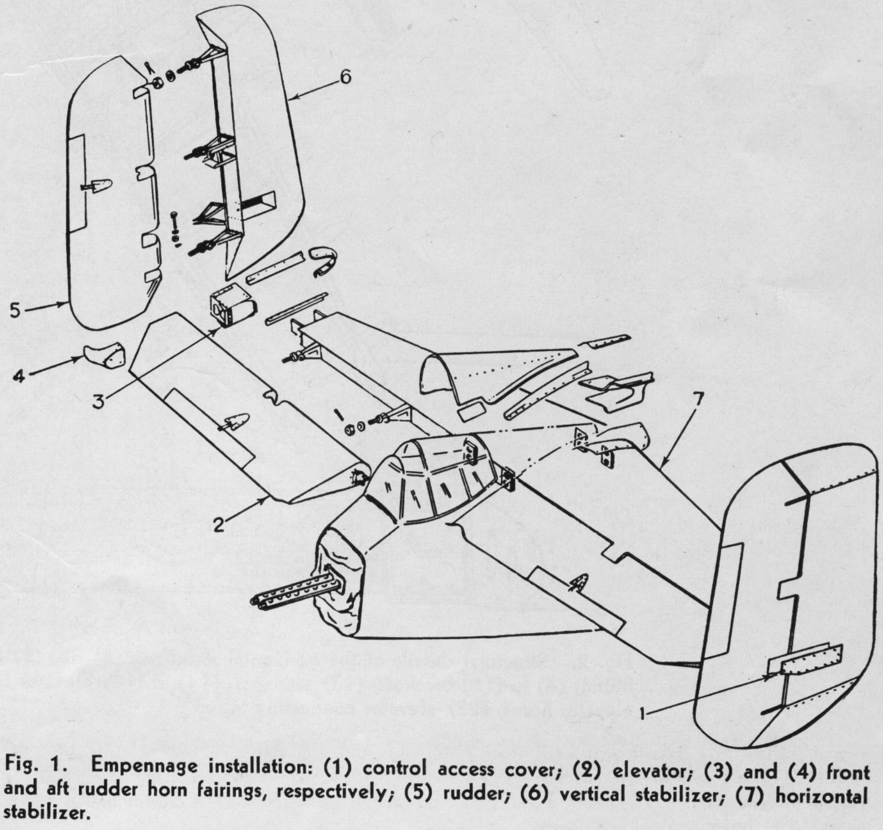


Fig. 1. Empennage installation: (1) control access cover; (2) elevator; (3) and (4) front and aft rudder horn fairings, respectively; (5) rudder; (6) vertical stabilizer; (7) horizontal stabilizer.

flanges along the top and bottom surfaces. Flanged holes lighten the structure and stiffen the spar web. The rudder and elevator false spars are U-shaped, formed from .032 24ST alclad. Trailing-edge ribs attach to these members, and brackets are used to attach trim tabs at three points along the flat surface of the spar.

The nose skins for both members are rolled from .025 24ST alclad and are riveted to main spar flanges and rib caps. Rudder nose skins are provided with flanged lightening holes. The rudder and elevator T.E. are U-shaped members of .025 alclad riveted to the rib tips. The trim tabs are constructed of sheet metal in the conventional manner.

The fabric covering of the elevators is Grade A mercerized cotton, doped and finished. It is attached to dimpled holes in the T.E. rib capstrips by countersunk sheet-metal screws inserted through dimpled washers. Doped reinforcing tape is placed along the ribs before the screws are inserted. After insertion of the screws and washers, a strip of finishing tape is placed over them to provide a smooth surface.

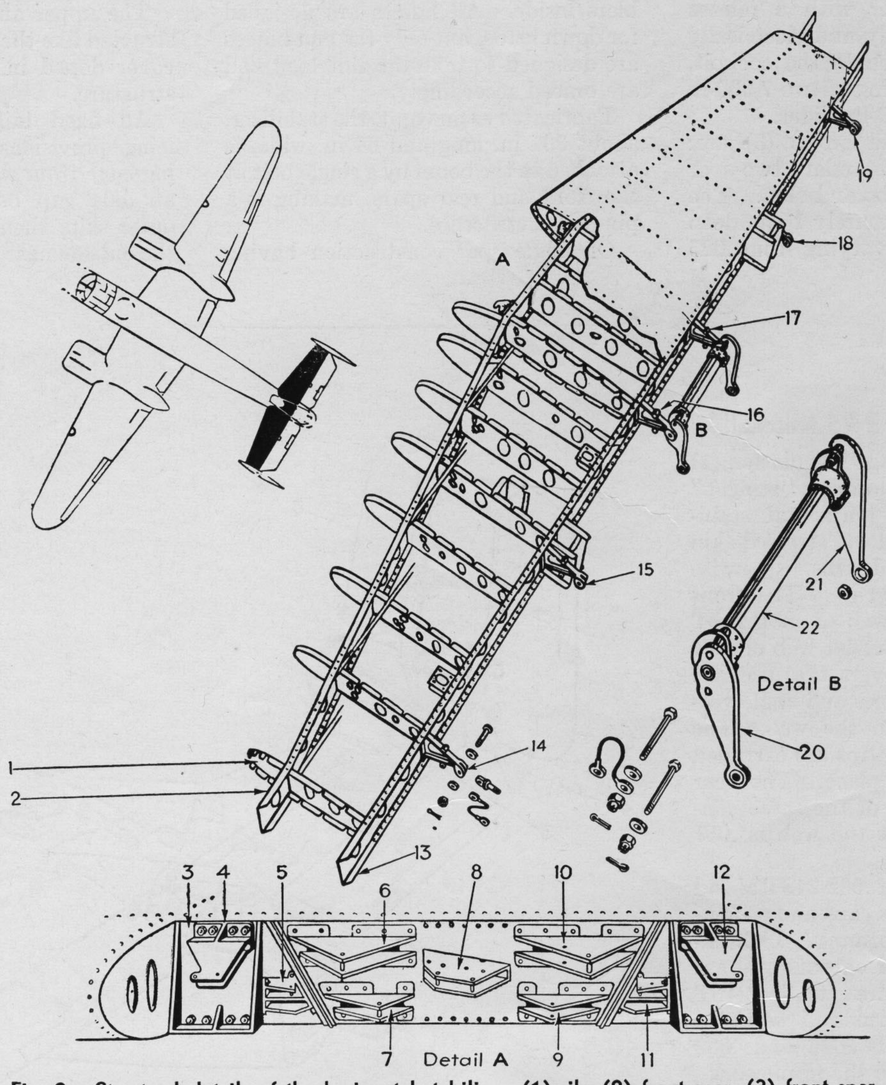
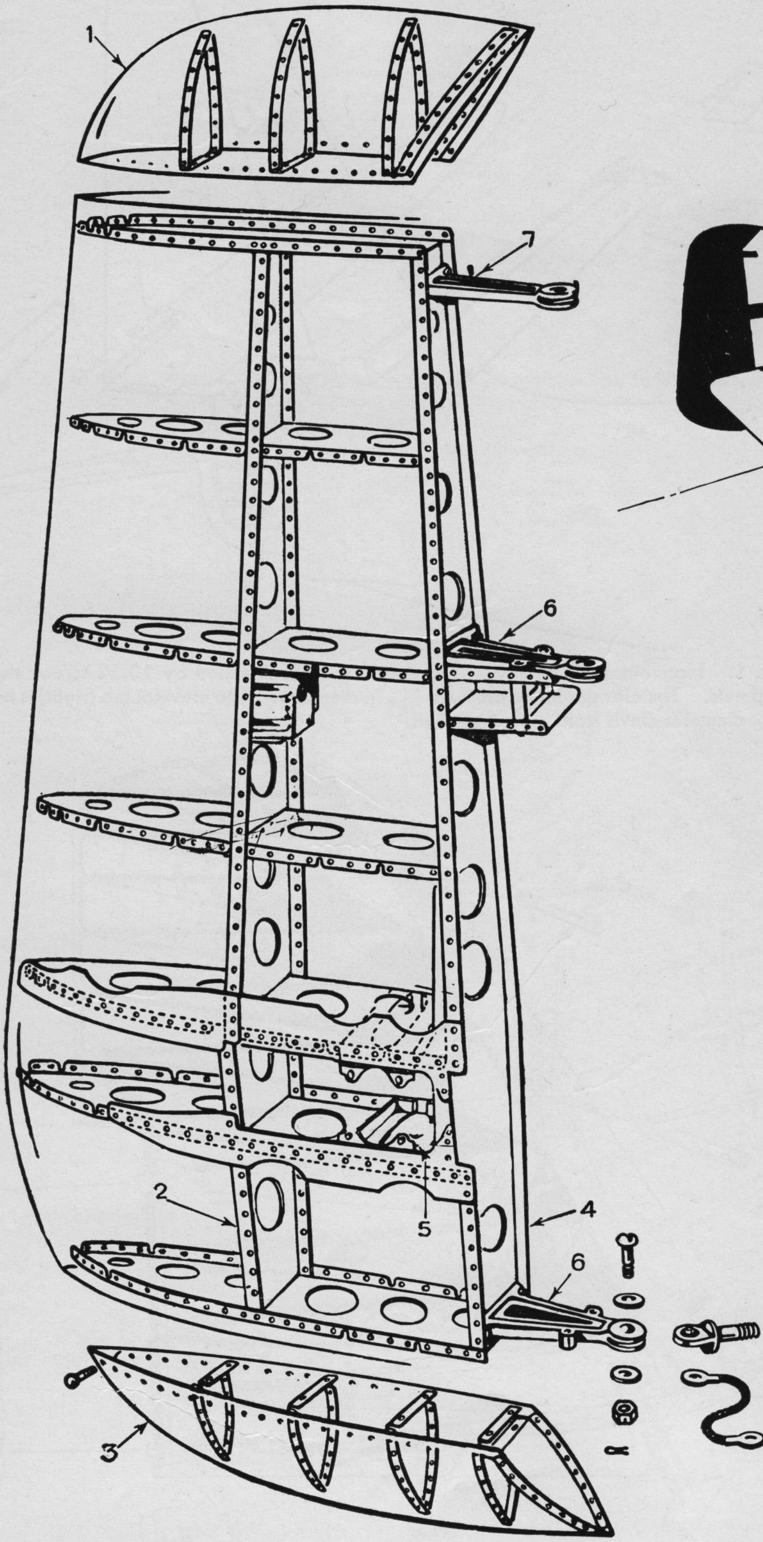


Fig. 2. Structural details of the horizontal stabilizer: (1) rib; (2) front spar; (3) front spar fitting; (4) to (12) brackets; (13) rear spar; (14) to (19) elevator hinge brackets; (20) (21) elevator horns; (22) elevator connecting tube.



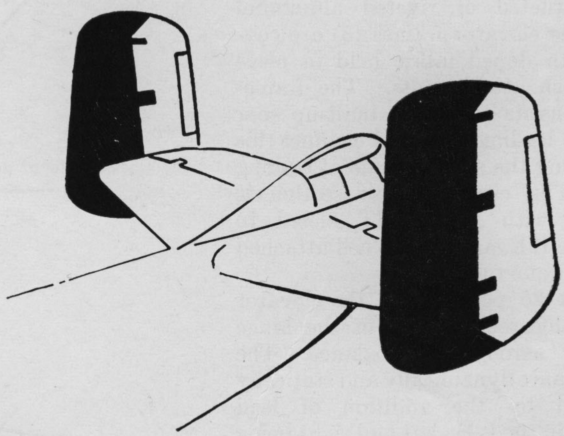


Fig. 3. Structural details of the vertical stabilizer: (1) tip assembly; (2) front spar; (3) lower tip assembly; (4) rear spar; (5) rudder control sheave support; (6) (7) rudder hinge brackets.

Douglas A-20

The A-20's horizontal stabilizer (1) is of two-piece, full-cantilever all-metal design, permitting interchangeability, left with right. It attaches to the fuselage with tension bolts and is given a 10-deg dihedral to elevate the tips above the wake of the engine nacelles.

Constructed of riveted aluminum alloy, the elevator frames (3) are covered with doped fabric held in place with flush attachments. The framework consists of a deep built-up spar near the leading edge and channel ribs connecting the spar to a metal trailing edge. The elevator nose section is covered with light 24ST alclad to form the L.E. and torque cell attached to the torque tube.

About 25 per cent of the elevator area is located forward of the hinge line for aerodynamic balance. The elevators are dynamically and statically balanced by the addition of lead weights in the L.E., left and right being interchangeable. Trim tabs have approximately 5 per cent of elevator area and are adjustable from the cockpit.

Of full-cantilever design, the vertical stabilizer is attached to the fuselage by means of tension bolts.

The rudder (2), similar to the elevator, is a riveted aluminum alloy frame, fabric-covered, with about 22 per cent of its area forward of the hinge line. It, too, is balanced by means of lead weights in the L.E. Trim tabs are 5 per cent of the rudder area and adjustable in flight from the cockpit.

The single type of vertical fin was chosen because it was believed to be less subject to flutter in case of combat damage and because of its greater simplicity of manufacture and better drag coefficient.

The tail cone (4) carries running lights and a formation light, elevator, and rudder fairings. It attaches to the fuselage by means of six bolts.

Horizontal Tail Surfaces	
Area (including fuselage area)	100 sq ft
Area (less fuselage area)	81.7 sq ft
Span	21 ft 1½ in.
Max. chord	80 in.
Distance from design gross weight, c.g. to ⅓ max. chord point	24½ ft, 295% M.A.C.

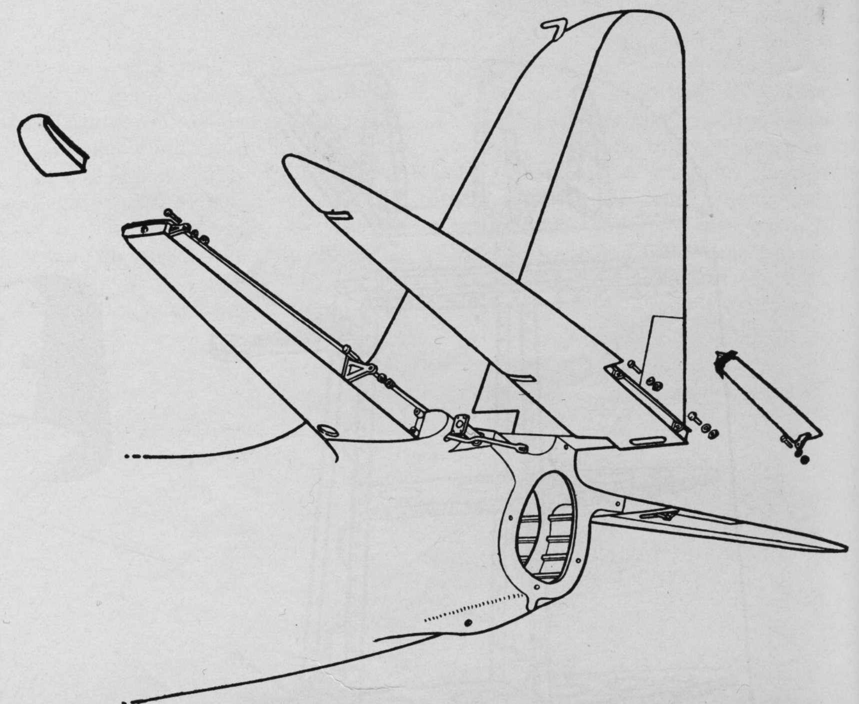


Fig. 1. Horizontal tail surfaces. The stabilizer tip is attached by 10.32 screws and elastic stop nuts. The elevator hinge bolts are $\frac{5}{16}$ in diameter. The elevator tab (right) is hinged on $\frac{3}{16}$ diameter clevis bolts with shear nuts.

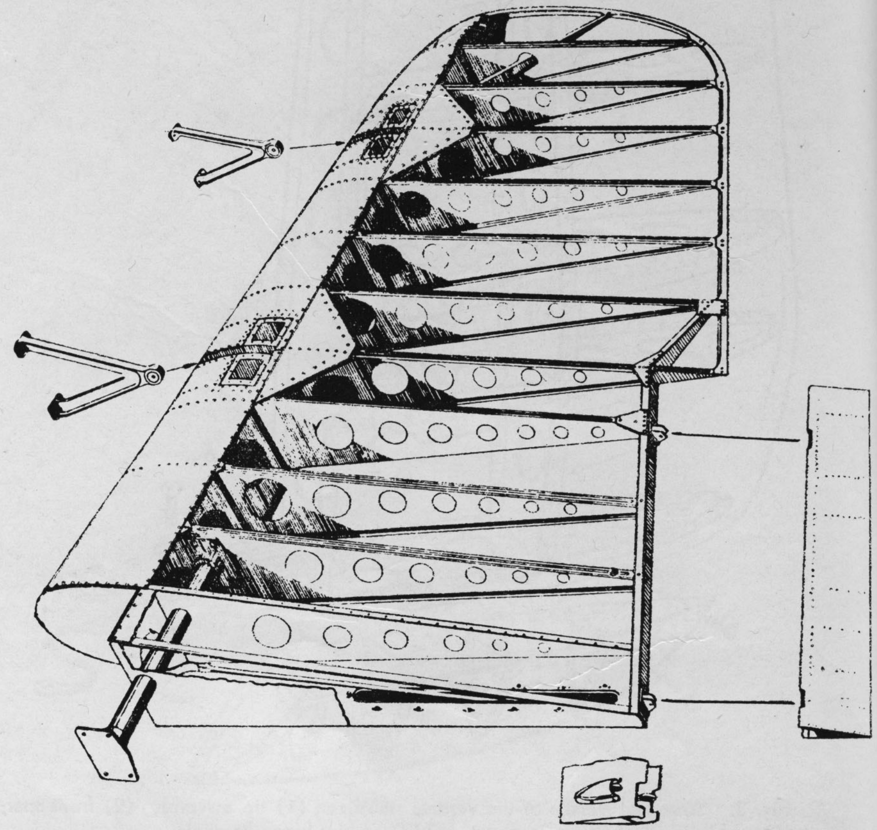


Fig. 2. The rudder is fabric-covered over an alclad frame and L.E. The tab is operated at the bottom by a rod in the recess shown. Lower recessed alclad sides are secured by $\frac{6}{32}$ rivet nuts.

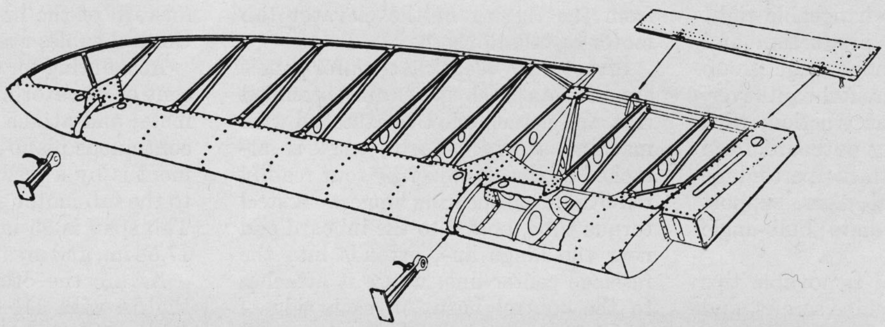


Fig. 3. The elevators are similar in construction to the rudder. The tab (right) is operated by an arm on the lower side. Hinge brackets are bonded as shown. Note the rigid bracing by both gussets and struts.

Horizontal Stabilizer

Area (including fuselage and elevator extensions)	60.8 sq ft
Area (less fuselage)	42.5 sq ft
Normal setting	+2 deg (relative to long axis)
Angular movement	None

Elevators

Area each	39.2 sq ft
Angular movement	Up 30 deg, down 20 deg
Total weight	Elevators, total weight, 88 lb, including 22.4 lb of weights; rudder, total weight, 83 lb, including 26.6 lb of weights

Vertical Tail Surfaces

Stabilizer:	
Area, total (less fairing)	24.8 sq ft
Normal setting	0 deg
Angular movement	None
Rudder:	
Area	35.1 sq ft
Angular movement	$22\frac{1}{2}$ deg right, $22\frac{1}{2}$ deg left
Total weight	Elevators, total weight, 88 lb, including 22.4 lb of weights; rudder, total weight, 83 lb, including 26.6 lb of weights

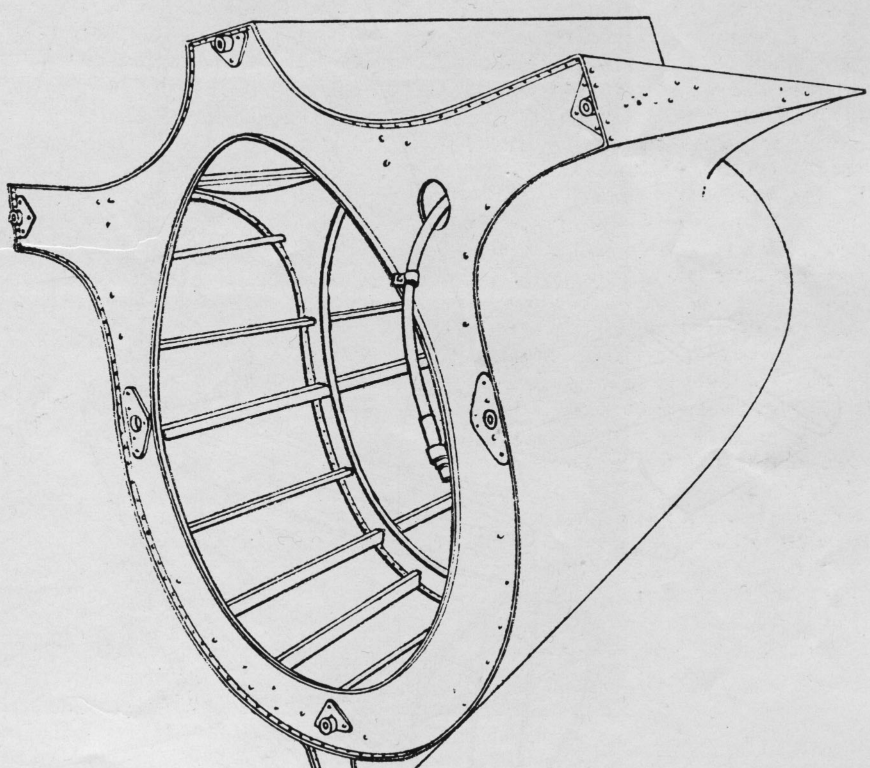


Fig. 4. The tail cone carries running lights and a formation signal light. Light cable enters through the face. The stubs at the upper sides are elevator fairings. The rudder fairing is at the top. Boltholes for attaching to the tail stub are seen on the face.

Curtiss C-46 Commando

Both stabilizers and elevator panels in the C-46 are interchangeable right and left, simplifying production and maintenance in the empennage group (1). The stabilizers are full-cantilever, metal stressed-skin construction, with three beams extending outboard from the root along constant percentage lines (2). Additional skin support is given by intermediate bulb-angle stringers.

Formed sheet-metal removable tips are attached with machine screws, and the stabilizer itself attaches to the fuselage with bolts through splice angles.

Since both panels are structurally identical, the only difference in their use on the right or left side would come from the rigging of the elevator tab motor installations.

Structurally identical elevator panels are all metal with two beams, stamped ribs, and detachable tips attached with machine screws. Each panel is attached to the stabilizer by four readily removable ball-bearing hinges. A steel torque tube, bolted to the inboard end near the hinge line, extends into the fuselage center line, where it attaches to the control horn, on each side of which there is a ball-bearing support.

Elevators swing over an arc ranging from 33 deg above horizontal to 17 deg below, and they have a total area of 98.7 sq ft. Dynamic balance is in the form of a streamlined weight mounted forward of the hinge line near the tip. Control cables are shown in (3).

Accounting for approximately 15 per cent of elevator area, trim tabs are all metal and attach to the elevator by a continuous piano-type hinge. Adjustment is by a push-pull tube extending to the tab motor shaft in the stabilizer. Tab span is 86 in., maximum chord is 17.58 in., and area is 9.35 sq ft.

As are the other empennage units, the fin with 115.4 sq ft of area is of full-cantilever, all-metal stressed-skin construction with six beams extending up from the root along constant

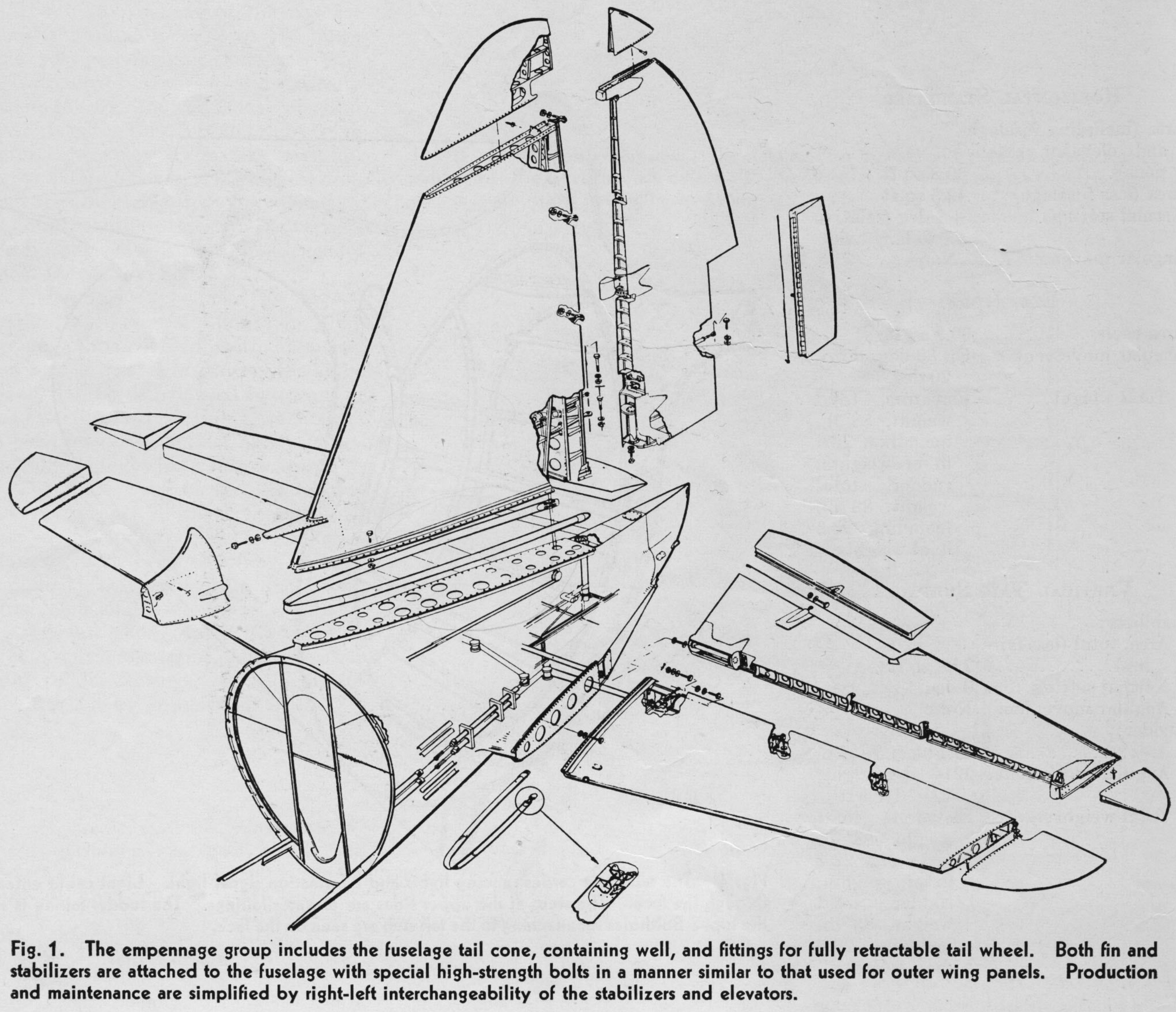


Fig. 1. The empennage group includes the fuselage tail cone, containing well, and fittings for fully retractable tail wheel. Both fin and stabilizers are attached to the fuselage with special high-strength bolts in a manner similar to that used for outer wing panels. Production and maintenance are simplified by right-left interchangeability of the stabilizers and elevators.

percentage lines. Additional skin support is given by intermediate bulb-angle stringers. Like other units, also, it has a detachable tip attached by machine screws, and the whole unit is attached to the fuselage with bolts through splice angles with a normal setting of 0 deg.

The rudder, like the elevators, has two beams and stamped metal ribs, 24ST alclad covered. It attaches to the fin by six readily detachable ball-bearing hinges. Area is 52.8 sq ft, and it swings 20 deg both ways from the plane's center line. A streamlined weight mounted forward of the hinge line near the top provides dynamic balance. Actuation is by a steel torque tube bolted to the lower end near the hinge line extending down into the fuselage, where it attaches, near a ball-bearing support, to a push-pull horn. Control cables parallel to the elevator control system (4).

The rudder tab, having approximately 13 per cent of the rudder area, is a combination trim and balance type. Area is 7.02 sq ft, length 65.12 in., and maximum chord, 16.65 in. As with other tabs, it is all metal and attaches by a continuous piano-type hinge.

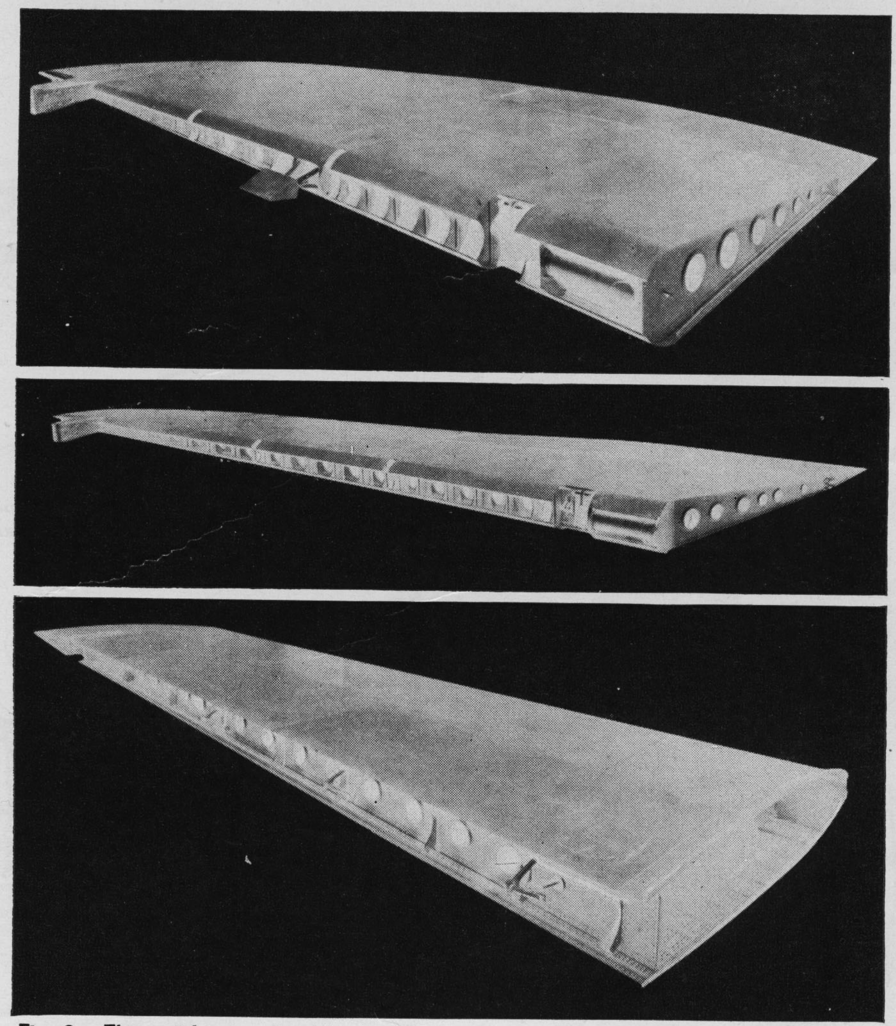


Fig. 2. The metal-covered rudder (top) has two beams, stamped ribs, and detachable tip, and attaches to the fin by six ball bearings. With 52.8 sq. ft of area, its arc is 20 deg to right and left of center line. The elevator (center) also has two beams, stamped ribs, and 24ST alclad covering. Attachment to stabilizer is by five ball-bearing hinges. The stabilizer (bottom) is of full cantilever all-metal stressed-skin construction with three beams extending outboard from the root along constant percentage lines and with additional skin support given by intermediate bulb-angle stringers. Like other empennage surfaces it has a removable tip.

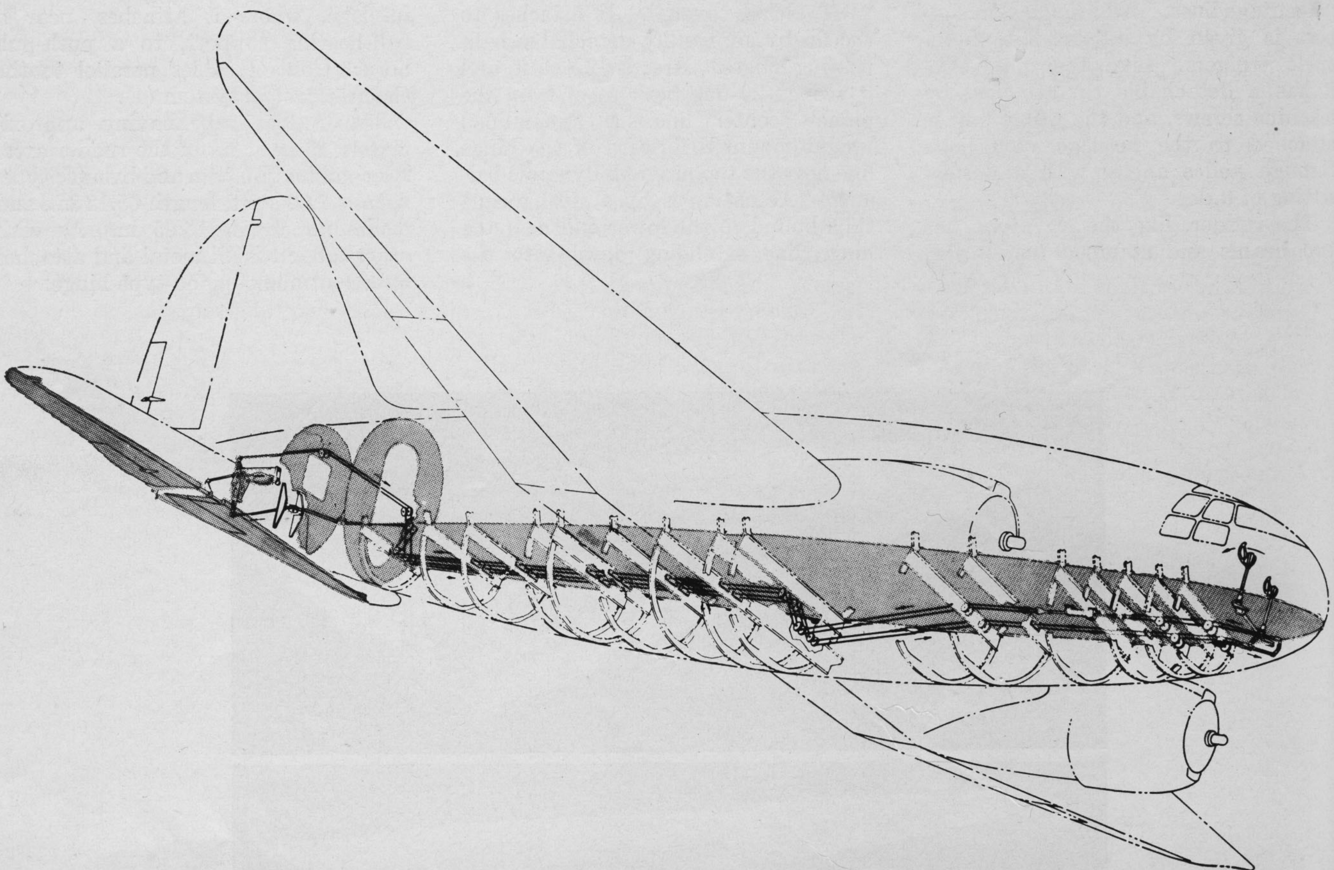


Fig. 3. Elevator control cables run from the pilot's cabin to the empennage through the top of the lower cargo compartments, where they are accessible for inspection and repair. A hydraulic boost cylinder is installed adjacent to the elevator horn so that power is applied direct to the bell crank operating the torque tube.

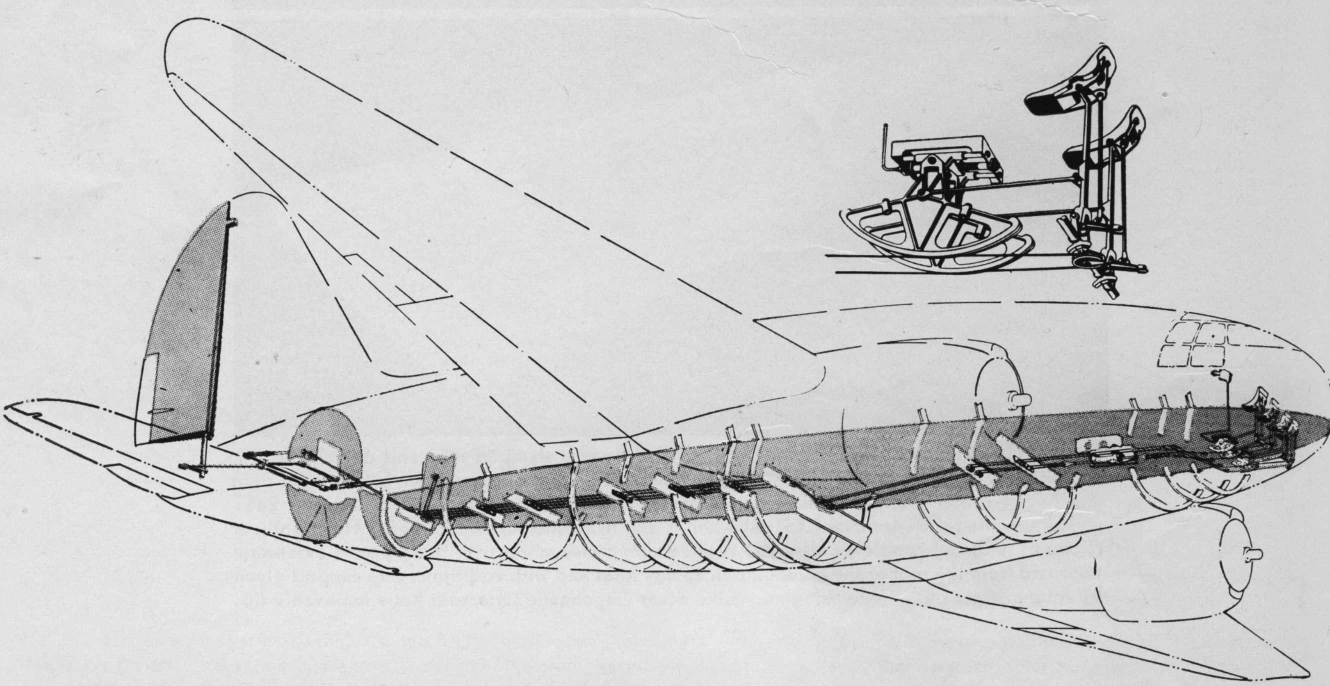


Fig. 4. Rudder control cables parallel the elevator control system and thus are as easily reached for servicing. Independent hydraulic brakes operate from conventional toe pedals shown in the detail inset at the right.

Lockheed P-38

The P-38 empennage consists of two booms—forming the tail cone—two vertical stabilizers, two rudders and tabs (1), one horizontal stabilizer, and one elevator and tab.

Outboard the aft empennage boom supports the rear portion of the stabilizer tips and is attached to the forward empennage boom by screws and plate nuts. The forward boom is a formed skin reinforced by stringers and hydro-pressed bulkheads, to which are attached the horizontal and vertical stabilizers, the latter being divided above and below the forward empennage boom.

The flush-riveted horizontal stabilizer (3) is built up in standard, all-metal airfoil style and is supported as a partly fixed ended beam from the two tail booms. It consists of two aluminum alloy shear beams and a skin of smooth sheet suitably stiffened by means of aluminum alloy extruded bulb angles. The rear spar carries the elevator hinge brackets and bearings, the end of the elevator torque tube, and the elevator tab-actuating unit. On the under surface, 3⅞ in. to the left of the plane's center line, is a plate nut for plumb-bob attachment, and on the leading edge at the center line is an eye for alternate radio antenna attachment.

Stabilizer tips are made with smooth aluminum alloy skin, flush-riveted to hydro-pressed 24ST ribs and channel strips, and are attached to the empennage boom by means of 40 screws around the inboard contour. The right and left stabilizers are interchangeable.

The elevator has an area of 24.5 sq ft and angular movement of 23 deg up and 8½ deg down. It is statically balanced by four weights, one in each boom and two at the center line. It is metal-covered and flush-riveted and its internal structure is similar to that of the stabilizer and other control surface units. Its trim tab, placed at the plane of symmetry, has an area of 1.73 sq ft and is controllable from the

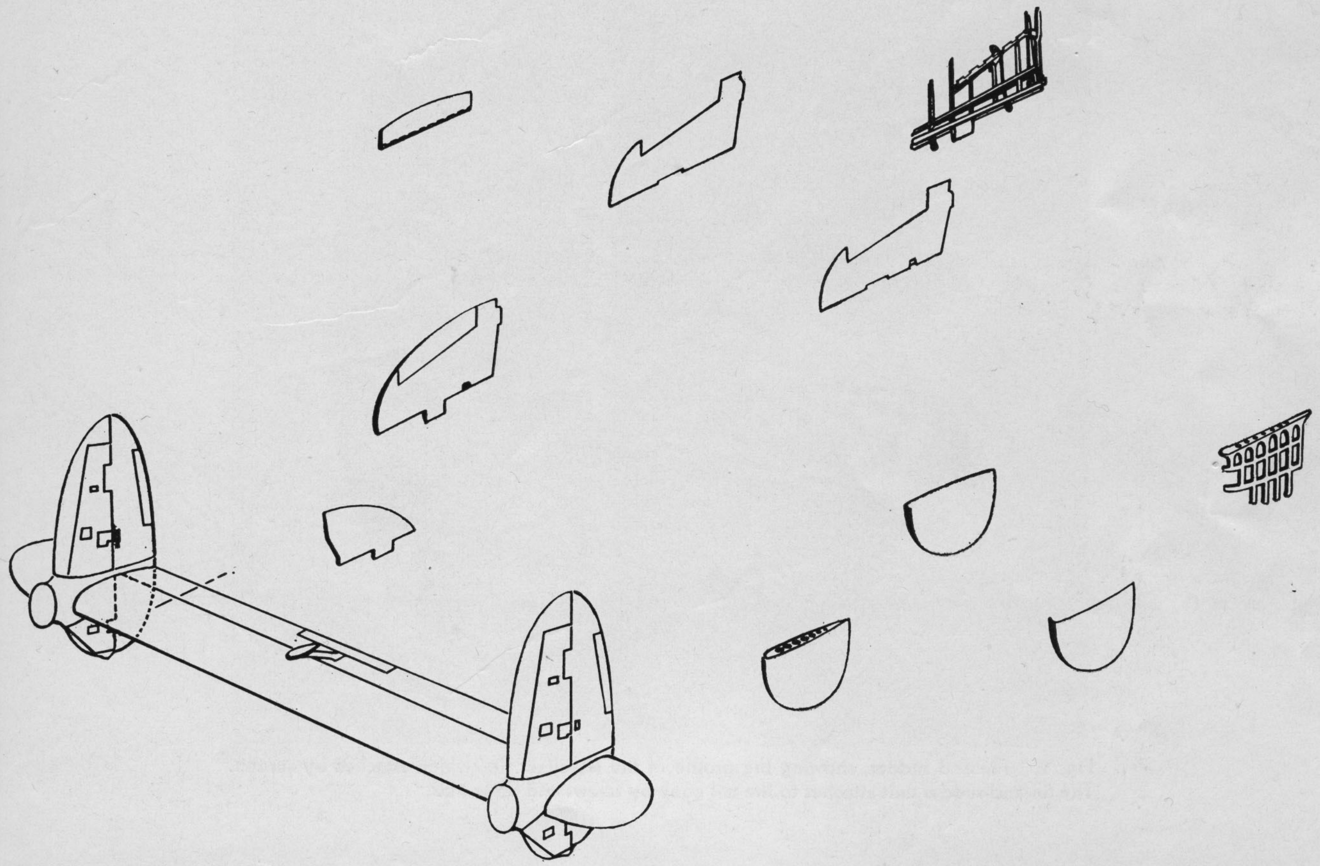


Fig. 1. The detail sketches in the upper row show components in the rudder assembly, starting at the right with the frame assembly and including skins and tab to form the complete upper rudder. The lower rudder assembly is also shown. The lower row shows (right) stabilizer tip frame, then skins and the complete unit.

cockpit. It attaches by means of stainless-steel piano-type hinges.

Vertical fins (2) are full cantilever and attach rigidly to the tail booms with no external bracing. They are made up of multiple-shear webs, ribs, and covering of aluminum alloy stiffened by aluminum alloy extruded bulb sections. They are constructed in two sections each, attaching above and below the empennage boom. In the upper sections are the rudder tab-actuating units, a navigation light showing on the outboard side only, one elevator control pulley, and two rudder tab-control pulleys. Each lower section carries one elevator-control pulley and a steel shoe to protect the lower tip against damage in the event of a tail-down landing. Rudder hinge brackets and torque tubes attach to the rear spars of the stabilizers. The right and left fins or vertical stabilizers are interchangeable. They have a combined area of 24.42 sq ft.

The all-metal, flush-riveted rudders have a total area of 21.36 sq ft and angular movement of 28 deg right and left. Tabs in the trailing edges have an area of 1.37 sq ft. Rudder balance weights extend forward of the hinge line into recesses in the rear edges of the fins.

The entire tail assembly is manufactured as a unit and is quickly detachable for repair.

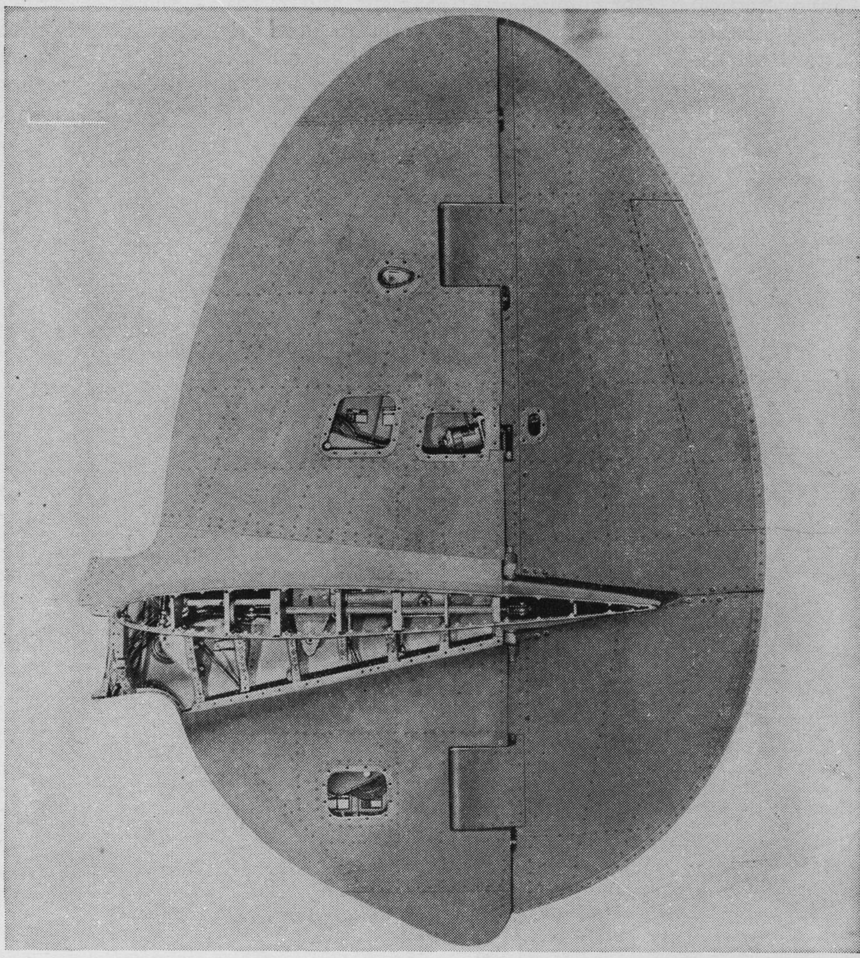


Fig. 2. Fin and rudder, showing the profile of the stabilizer tip, which attaches by screws. The fin-and-rudder unit attaches to the tail cone by screws and plate nuts.

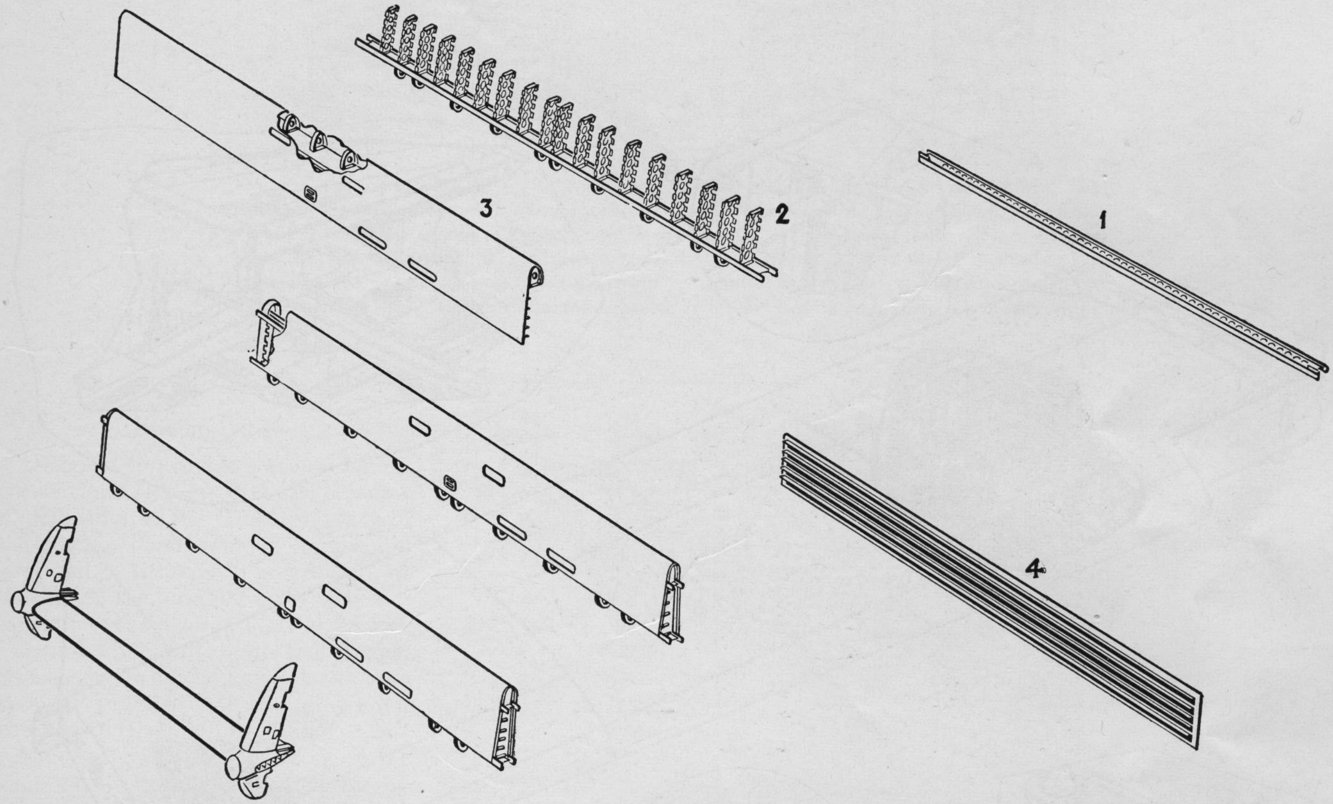


Fig. 3. The horizontal stabilizer is comprised of: (1) forward spar; (2) rear spar and ribs; (3) lower skin and nose ribs; (4) upper skin and stringers.

Avro Lancaster

The Lancaster horizontal stabilizer construction is in two halves bolted together at the fuselage center line and is covered with metal skin riveted to the structure. It is of two-spar construction. Attachment of the stringers to the ribs is by means of attachment brackets (1).

Elevators contain welded-steel tube ribs, tubular steel spar, and metal leading edge. A balance weight is welded to the L.E. nose ribs.

A reinforcing plate is used in the stabilizer-to-front fin post joint (2).

The Lancaster tail assembly is the twin-fin type.

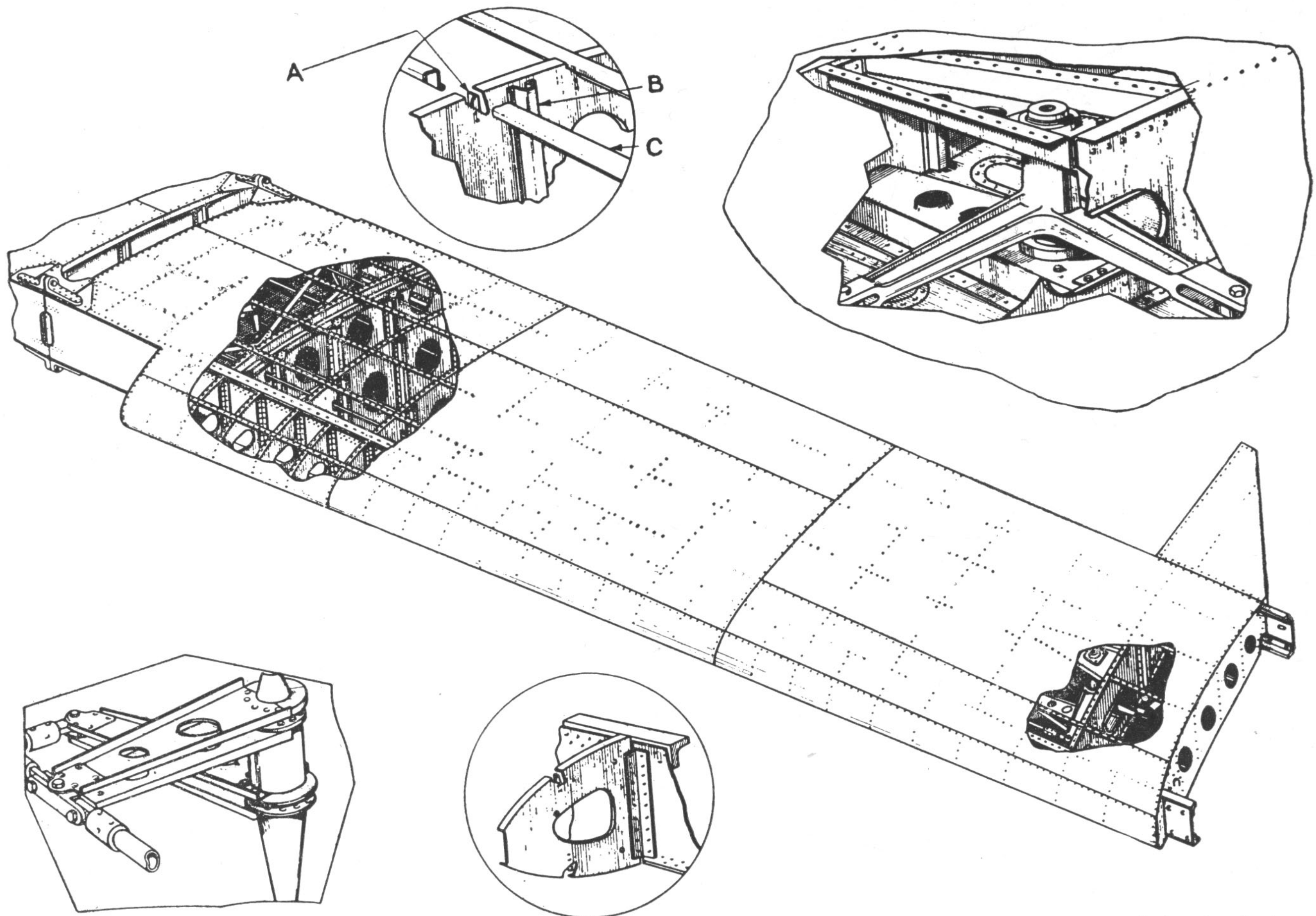


Fig. 1. Cutaway view showing the construction of an Avro Lancaster stabilizer. Sketch at upper left shows structural details of ribs and stringers reinforcing strip (*A*); vertical channel (*B*); stringers (*C*). At upper right is the detail of the control crank and mounting. Sketch at lower left shows control rod connections. At lower right is detail of the attachment of the nose rib.

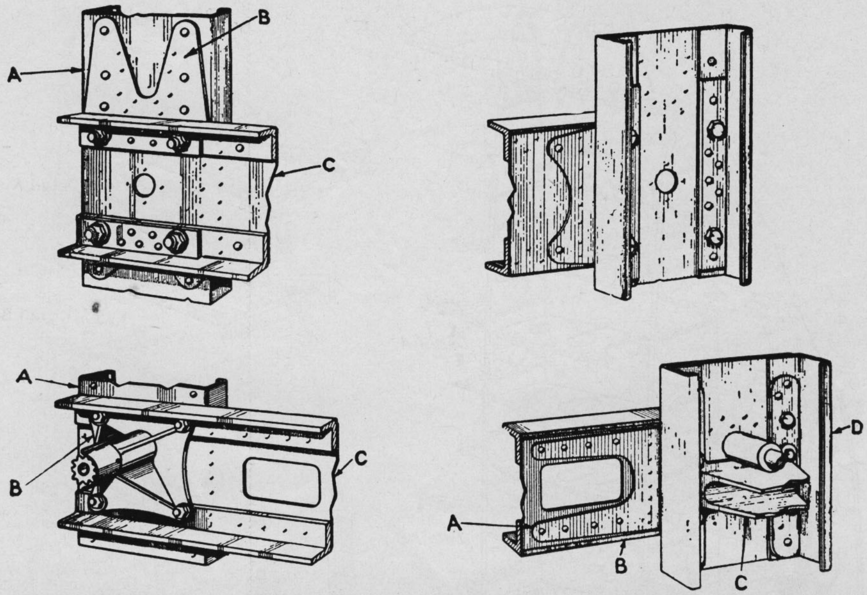


Fig. 2. At the left are details of the Avro Lancaster stabilizer-to-front fin post joint. The sketch at the top left shows, looking forward, fin post (*A*); reinforcing plate (*B*); stabilizer front spar (*C*); while the sketch at the top right is of the same section but looking aft. The lower sketches depict the attachment of the rear spar to the rear fin post; the sketch at the left the view aft showing rear fin post (*A*); rudder trim tab control bracket (*B*); stabilizer rear spar (*C*). The lower right sketch shows, looking forward, reinforcing plate (*A*); spar (*B*); rudder hinge bracket (*C*); rear fin post (*D*).

Boeing B-17

Designed to provide a secure bombing platform, the greatest single factor contributing to the famed stability of the Flying Fortress is the unusually large tail. Although it was known at the time, the original Fort was designed so that a large vertical fin was essential to stability, and the original fin was somewhat larger than the then accepted practice. It was puny compared with the final installation.

Some of the design features of the final dorsal fin were dictated by incorporation, in 1940, of a tail gun position, while other features were the result of redesign to achieve still greater stability. Pilots reported the stability so complete that the plane could be flown on tabs alone without using the rudder, or with ailerons and elevators without the rudder, or without resetting the trim tabs, a fact that enabled many a battle-damaged Fort to return its crew safely to Allied territory, despite the loss of large portions of its tail.

The horizontal tail surfaces have an area of 331.1 sq ft, span of 43 ft, maximum chord of 125 in., and a distance of 451 in. from normal c.g. to one-third maximum chord point. The span places the tip directly aft of the outboard engine nacelle.

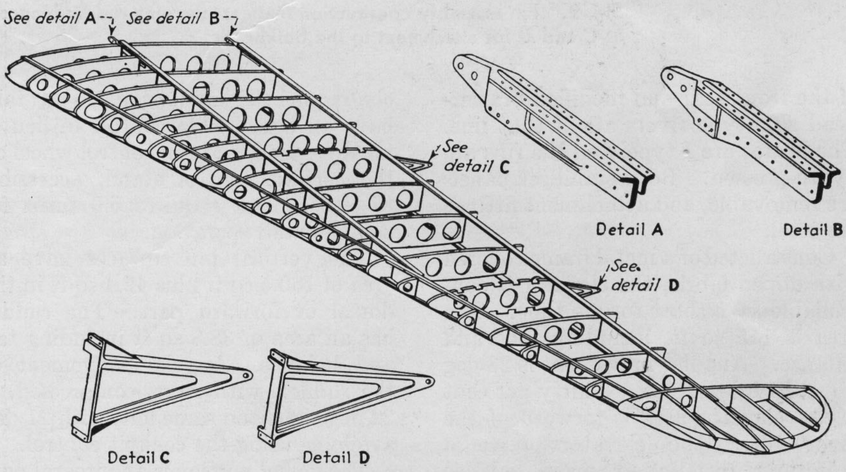


Fig. 1. Stabilizer assembly. Note that the front spar does not extend to the tip end. The L.E. and rear spar take over as the shear-carrying structure from the end of the front spar to the tip (8 ft). Stabilizer terminals at the fuselage are shown at details *A* and *B* and elevator hinges at *C* and *D*.

The stabilizer has an area of 250.6 sq ft and is set at 0 deg relative to the longitudinal axis. It is of two-spar construction with web-type spars made of 24ST web sheet and extruded spar chords, rolled 24ST spanwise stiffeners reinforcing the interspar skin, and hydro-pressed 24ST ribs. The front spar extends 230 in. to within 8 ft of the tip end. The longer rear spar extends to the tip joining point (1).

The leading edge and rear spar take over as the shear-carrying structure from the point where the front spar stops to the end of the tip. The alclad horizontal stabilizer has skin lap joints. Attachment is by flush riveting forward

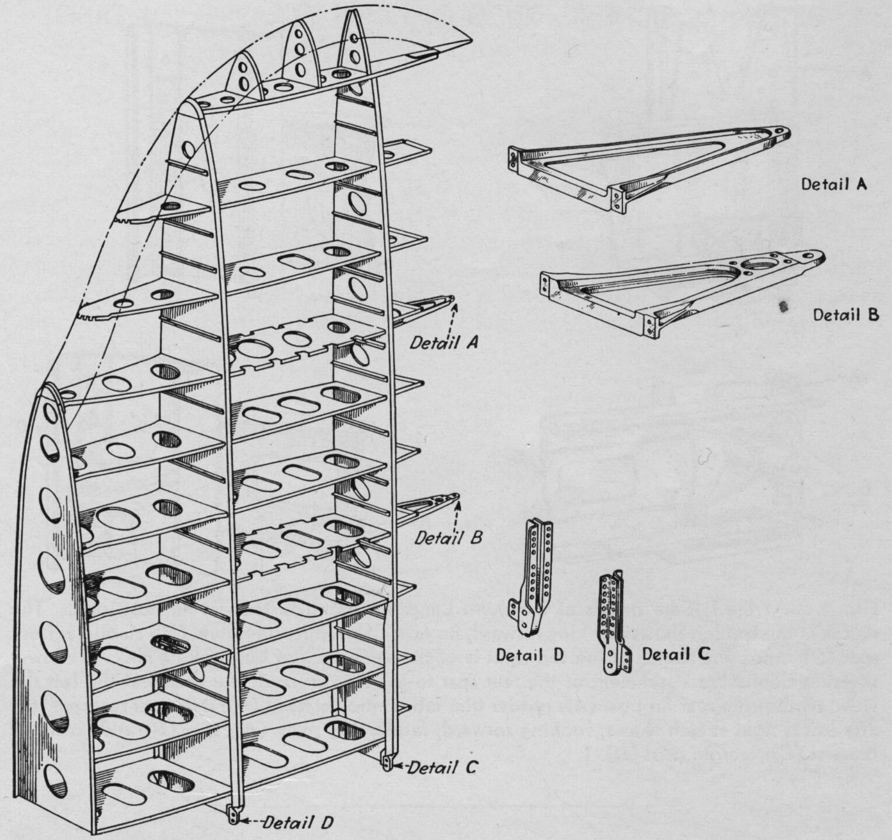


Fig. 2. Fin assembly construction features, showing rudder hinges at *A* and *B*, and terminals at *C* and *D* for attachment to the bulkheads.

of the front spar and modified brazier-head skin-type rivets aft of that line. The beams are I type, and the ribs are hydro-pressed. Both stabilizer panels are removable, and attachment fittings are steel.

Constructed of a metal frame covered with doped fabric, the elevator is controllable by a short torque tube. The area is 115 sq ft, including tabs and balance. Angular movement is 23 deg up and 14 deg down. Thirty per cent of the elevator area is forward of the hinge line. The elevators have a uniformly distributed mass balance such that the chordwise elements are 100 per cent statically balanced about the hinge center line. The dynamic balance coefficient about the body center line is approximately zero. The chord aerodynamic balance is 27 per cent.

An aluminum alloy trim tab of 5.6 sq ft area and with an angular movement of 11 deg up and down is attached by a piano hinge to each elevator near the fuselage. The external contour of the tab is flat on top and curved ¾ in. maximum at the center of the 11-in. chord on the underside. The tabs have an irreversible control in lieu of mass balance, and the control wheel on the cockpit control stand, accessible to either pilot, requires 5.9 turns for complete tab operation.

The vertical tail surfaces have an area of 100.5 sq ft plus 42.4 sq ft in the dorsal or forward part. The rudder has an area of 38.8 sq ft including tab and balance. Angular movement of the rudder, with stops compressed, is 22 deg right and same left, with 21 deg available using the cockpit control.

The dorsal portion is an integral part of the fuselage top and consists of hydro-pressed ribs and extruded stiffeners covered with 24ST alclad. It is assembled separately and joined to the fuselage as a completed assembly.

The vertical fin (2) is similar in construction to the horizontal stabilizer; a two-spar, web-type, formed of 24ST sheet and with 24ST extrusions for spar chords. Spanwise stiffeners are rolled 24ST and ribs are hydro-pressed stampings of 24ST sheet stock. A portion of the fin load is carried forward through the dorsal section.

The rudder (3) has a metal framework with hydro-pressed nose ribs forward, and tail ribs aft, of the spar. The entire frame is covered with highly processed fabric which, when properly applied, provides a control surface with a minimum tendency to flutter because of dynamic air forces. Actuation is about three hinge points by a rudder torque tube controlled through a cable system from the cockpit.

The rudder has a uniformly distributed mass balance such that the chordwise elements are 100 per cent statically balanced about the hinge center line, and the dynamic balance coefficient about the body center line is approximately 0. Chord aerodynamic balance is 25 per cent.

The aluminum alloy trim tab—3.4 sq ft in area—is installed at the lower trailing edge. It has irreversible controls with a control wheel aft of the cockpit control stand. Approximately 6.9 turns of the wheel are required for complete tab operation. Angular movement is 22 deg each way.

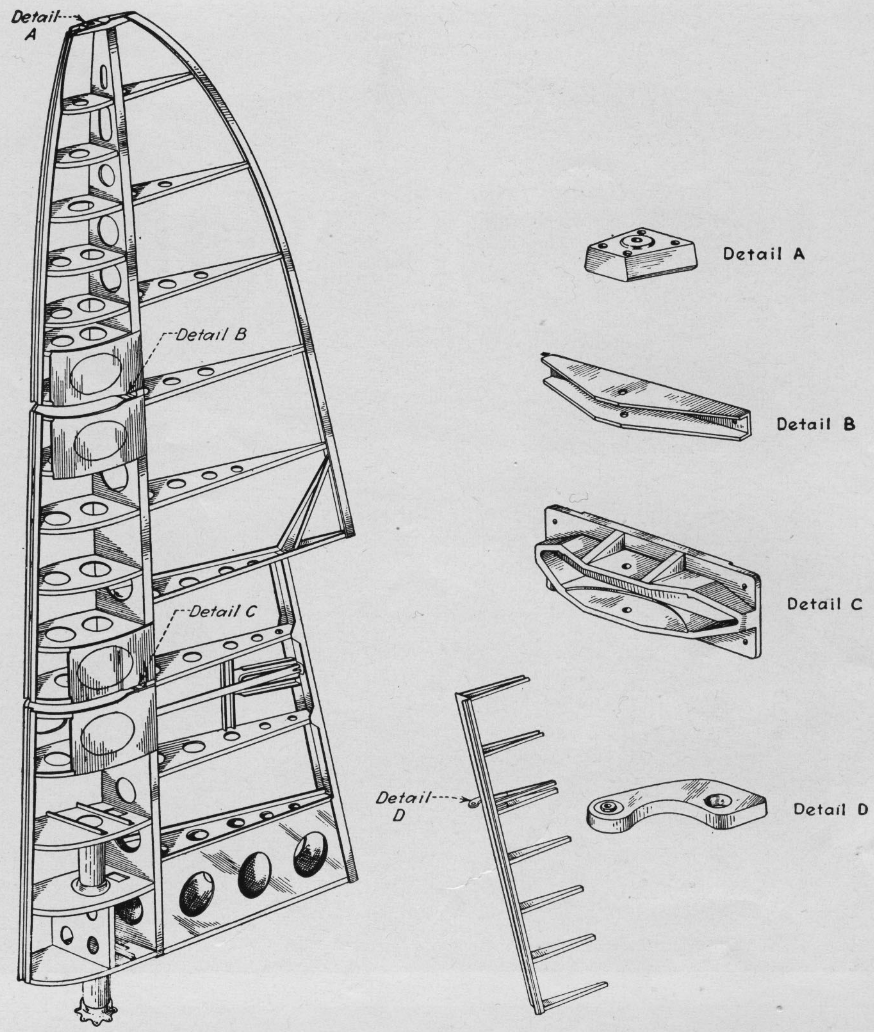


Fig. 3. Rudder assembly construction features, with top hinge shown at detail *A*, center hinge at *B*, lower hinge at *C*, and tab-actuating hinge at *D*. The rudder torque tube at the bottom attaches to the control quadrant.

Consolidated Vultee B-24

The horizontal tail surfaces of the Liberator's original, twin-rudder assembly design have NACA section 0015 and contain 192 sq ft of area. Span is 26 ft and the maximum chord 7 ft $8\frac{3}{16}$ in. The distance from the design gross weight c.g., assumed at 25 per cent M.A.C., to the one-third maximum chord point is 33.40 ft, which is approximately $3\frac{1}{2}$ times M.A.C. The stabilizer area, including elevator balance, is 140.5 sq ft. Its normal setting relative to the longitudinal axis is 2.5 deg (1).

The elevator (2) has an area of 67.1 sq ft with 51.5 sq ft aft of the hinge line. Angular movement is 30 deg up and 20 deg down. Aerodynamically balanced, all spanwise elements of the elevator are statically balanced about the hinge line. Tabs in the trailing edge have an area of 4.95 sq ft and are controlled by an irreversible mechanism.

Vertical tail surfaces have NACA section 0007 with a fin area of 123 sq ft and a rudder area of 48.8 sq ft. The rudders (3) are aerodynamically balanced and fully balanced statically. Spanwise elements are statically balanced about the hinge line. The tabs have a total area of 3.1 sq ft and are equipped with irreversible controls. Rudder angular movement is 10 deg right and left of center.

The new single tail assembly, designed at AAF request, required few changes in the original aft fuselage structure. The later stabilizer was designed to fit the old type fittings, with the dorsal fin attaching to the new structure. A front fin spar attaches to a new, built-up bulkhead.

All tail assembly control surfaces are of aluminum torque box and rib construction, fabric-covered. The stabilizer, constructed as a separate assembly, has a smooth sheet-metal skin and is attached to the fuselage with only four fittings to facilitate replacement. The entire tail assembly is mounted just enough forward of the tail gunner's compartment so that the T.E. does not obscure the gunner's vision.

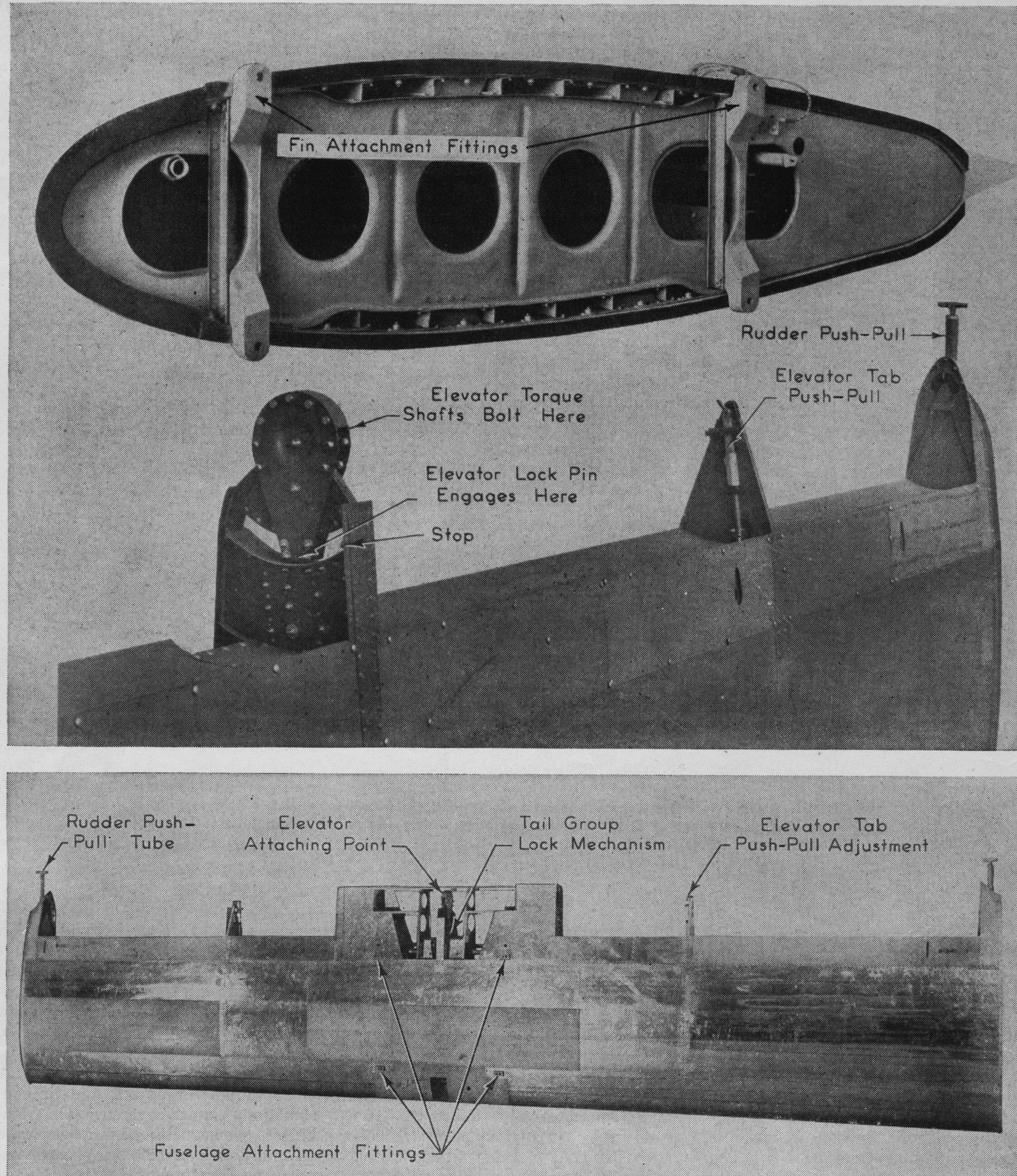


Fig. 1. Close-up (1) showing details of the horizontal stabilizer depicted in (1*a*). Carrying the entire load of the tail group, four aluminum alloy forgings, riveted to stabilizer spars, are used for attachment to similar fittings on the fuselage. Eight bolts are used in the stabilizer-fuselage connection.

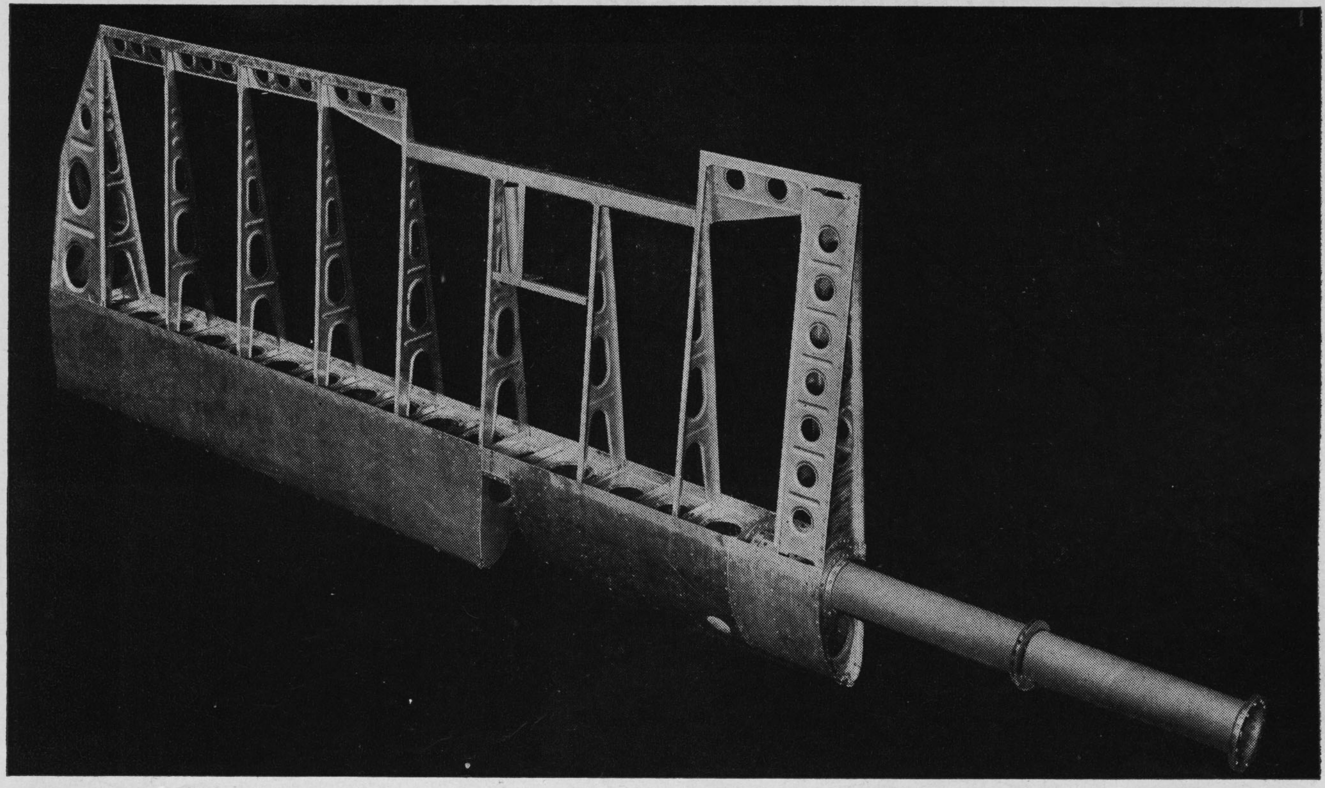


Fig. 2. Details of the elevator structure. Torque tubes of the two units are bolted together through a control lock fitting mounted on the stabilizer at the center line of the plane. Hinge bearing supports are aluminum alloy forgings bolted to spars, and elevator movement is limited by stops.

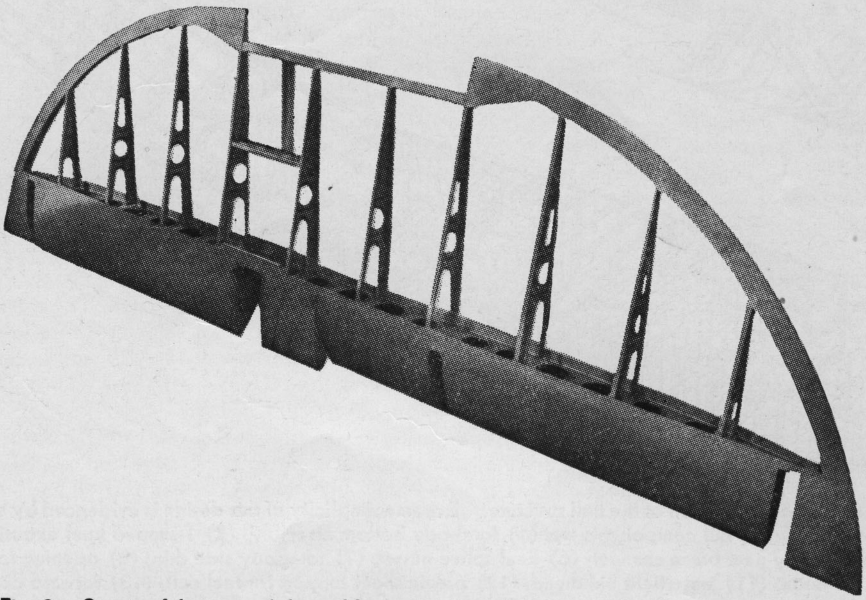


Fig. 3. Structural features of the rudder on a twin-tail version of the B-24. In this version, rudders are interchangeable if the horns are reversed.

Chapter IV. FUSELAGE, BODY, AND HULL DESIGN

PART 1. SINGLE-ENGINE AIRCRAFT

Republic Seabee

The Seabee hull (1),* designed so as to permit a major portion of riveting to be done by automatic machinery, consists of three separate assemblies: forebody, afterbody, and stern. Assembled, it has six watertight compartments: three in the forebody, two in the afterbody; the stern is the last.

The forebody of the hull is composed of four subassembly units: deck (cabin floor), two sides, and bottom. The deck is made in three sections: forward, middle, and aft. The forward section is a single .051 24SO pressing, subse-

* The numbers in parentheses refer to the illustrations.

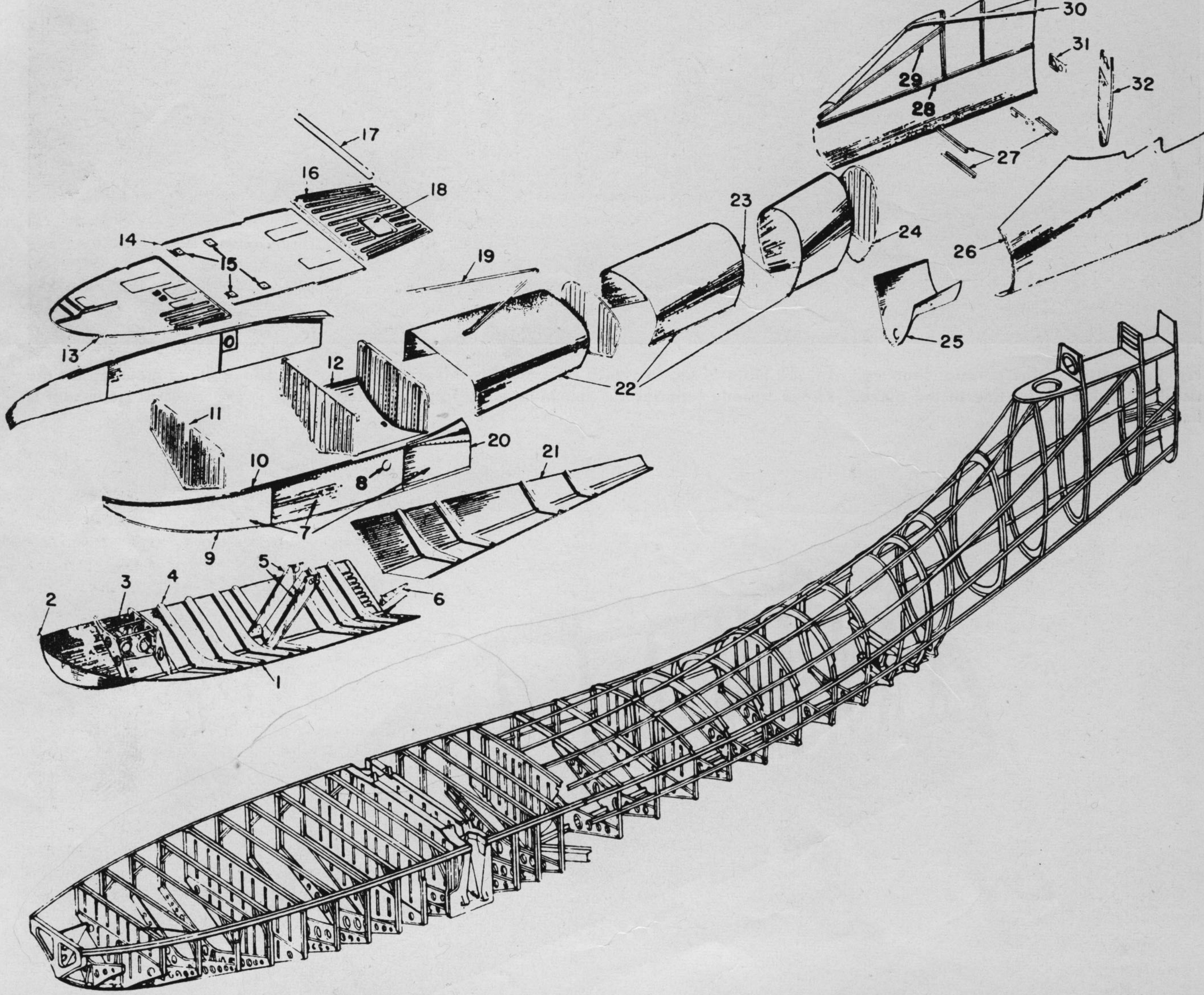


Fig. 1. At the top is seen an exploded relation of the hull structure. Extreme simplicity of this design is evidenced by comparison with the conventional hull structure shown above. Hull components are: (1) forebody bottom assembly; (2) T-shaped keel extrusion, (3) battery support; (4) hat-section stiffener; (5) landing gear brace channel; (6) keel splice gusset; (7) forebody side skin; (8) opening for landing gear hull shaft; (9) chine; (10) Z-section longeron; (11) watertight bulkhead; (12) plastic sheet support for fuel cell; (13) forward deck section; (14) middle deck section; (15) seat track supports; (16) aft deck section; (17) transverse angle for attachment of wing strut fitting; (18) fuel cell cutout; (19) cabin attachment angle; (20) first step; (21) afterbody bottom assembly; (22) afterbody upper section skins; (23) tail-wheel auxiliary bulkhead; (24) tail-wheel watertight bulkhead; (25) second step (structural fillet); (26) stern skin; (27) transverse stiffeners; (28) longitudinal stiffener; (29) diagonal stiffener; (30) channel stiffener for fin cutout; (31) channel for attachment of stabilizer rear spars; (32) rear closure bulkhead.

quently heat-treated and reinforced with three hat sections, two transverse, one longitudinal, supporting the cockpit flight controls. The edge of this section has an upwardly turned flange for assembly to the sides by riveting.

The deck middle section is .025 R-301W stiffened by four longitudinal hat sections supporting the front seats and landing gear brace channels. Margins of the middle section also are upwardly flanged for attachment to the sides and to the front deck section. Attachment to the rear deck is by a lap joint. A 1/8-in. R-301W Z-section longeron is between the middle section and the sides and becomes a simple angle where it overlaps (for about 10 in.) the front and aft deck sections.

The aft section of the deck is a single .051 24SO beaded pressing, subsequently heat-treated and having upwardly turned flanges on the sides. At the rear, the deck aft section overlaps the forward skin of the afterbody, also the step bulkhead. A cutout is provided in the aft deck section for access to the fuel cell (located between the middle and aft bulkheads).

Sandwiched between the flange junctions of the deck skins, the first two watertight bulkheads are heat-treated .040 24SO beaded pressings.

The forebody sides are .064 R-301W made up in three sections flanged outwardly at the chine, where it joins the bottom subassembly flange.

At the bow, forward of the front bulkhead, the bottom consists of left and right .072 61SW skins, made in a draw die. From the forward bulkhead to the step, the .051 R-301W skin (made on a bending brake) is reinforced by seven hat-section transverse stiffeners having greatest depth of about 4 in. at the keel. An external reinforcing angle, extending from the forward bulkhead to the step, is on the underside of the chine.

The keel, a T-shaped 14ST extrusion provided with drain plugs for each watertight compartment, runs aft of the first step for splicing to the keel of the afterbody.

Various simple structures within the forebody serve to support the battery, landing gear mechanism, and hydraulic pump, and also provide anchorage for safety belts.

The afterbody—the hull section between steps—is comprised of an upper section and the bottom as subassembly units. The upper section is fabricated from three pieces of .051 R-301W, each

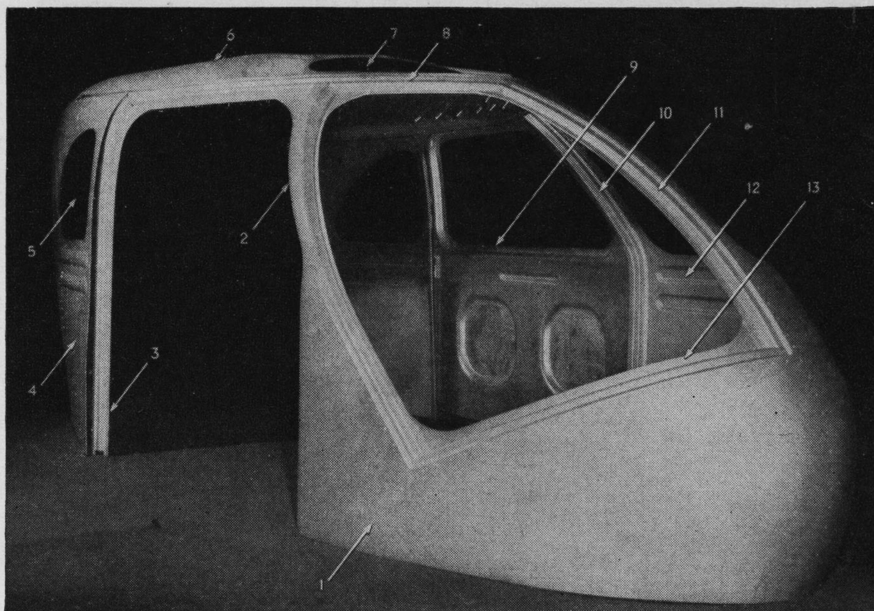


Fig. 2. Cabin superstructure frame setup: (1) right bow panel; (2) double front-door post; (3) rear right-door post; (4) rear side panel; (5) side window; (6) monopiece roof; (7) crown window; (8) crown bow frame; (9) left side door; (10) single front-door post; (11) center bow frame; (12) left bow panel; (13) lower bow door post. Fabrication simplicity is typified in the cabin fixed superstructures where the side panel is blanked from a single piece and formed with stiffening beads and contour in one operation. The cabin rear primary structure attaches to rear side skins of the superstructure and encloses the baggage compartment decked by the fire wall.

developed from a flat pattern, joined by simple lap joints. Rivets through the lap joint between the first and second skins pick up the flange of the forward watertight beaded bulkhead.

The bottom of the afterbody is a single sheet of .051 R-301W (formed on a bending brake) reinforced by four hat sections, as in the forebody.

Indicating the sturdiness of the hull bottom structure, no dishing or skin ripples were observed after more than 600 water landings.

The bulkhead at the second step supports the tail wheel. It is formed as an .040 24SO beaded pressing, subsequently heat-treated. At the lower portion of the bulkhead is a bearing plate reinforcement for attachment of the tail wheel. The bulkhead flanges face outward and are sufficiently wide to provide a foundation for a butt joint between the afterbody rear skin and stern skin. The splice is further reinforced at the bottom by a .051 R-301W structural fairing.

The stern consists of two subassemblies, left and right halves, comprising a clamshell skin structure of .040 R-301W with a cutout at the rear top portion beneath the fin. Each clamshell half has a single longitudinal and single diagonal Z-section stiffener, two vertical angle stiffeners for the stabilizer support, and a channel section for stiffening the edge of the cutout and to absorb drag loads from the stabilizer.

All these members are attached to the skin by automatic riveting. The clamshells are assembled with a riveted lap joint on all of the bottom and on the forward top. At the rear they are attached to the rib-shaped closure bulkhead.

Across the top of the cutout, a transverse angle serves as a fitting for attachment of the front spars of the stabilizers and fin. About 15 in. back of this angle member is a deep channel for attachment of the rear spars of the stabilizers. The rear spar of the fin attaches to the closure bulkhead aft of the stern.

A series of tubes, one leading from each of the watertight compartments in the hull, is grouped in the cockpit under the rear seat for attachment to a bilge pump, and numerous handholes are provided for inspection and servicing.

Comparison of key factors in the construction of the conventional and simplified hulls is given below:

	Conventional	*Simplified*
Parts	362	63
Man-hours	590	20
Rivets	6,500	2,400
Weight, lb	318	298

Cabin lines have been established by analytic geometry. Mathematical fairing not only greatly reduced tedious lofting time but made possible rapid and precise manufacture and inspection of jigs, tools, and dies.

The cabin consists essentially of two main sections: (*a*) rear primary structure, tying the wing and engine installation to the hull; and (*b*) a forward section superstructure (2), enclosing the cabin proper.

Consisting of two beaded pressed sections, .040 upper and .025 lower, with a center cutout for access to the baggage compartment, the rear primary structure forward bulkhead supports the wing front spars and is reinforced by .064 hat-section uprights at each side. The lower end of each upright is riveted to an external fitting which connects the wing brace strut to the hull. The upper ends of the uprights connect to an inverted hat-section extrusion which serves as cross-ties between the front spars of the wing panels and also supports the front end of the engine mount. Similarly, over the main step bulkhead there are two other upright hat sections which attach to another inverted transverse hat section connecting the rear spars of the wing panels and also supporting the rear end of the engine mount. The top of the rear primary section is an aluminum-coated .019 low-carbon steel fire wall.

The side skin of the rear primary structure—.040 R-301W stiffened by secondary vertical channels—is in two sections connected along the mating flanges at the trailing end of the cabin structure.

The cabin enclosure, or forward superstructure, includes an .091 61SW crown bow member, five doorframe uprights, and .040 61SW skins.

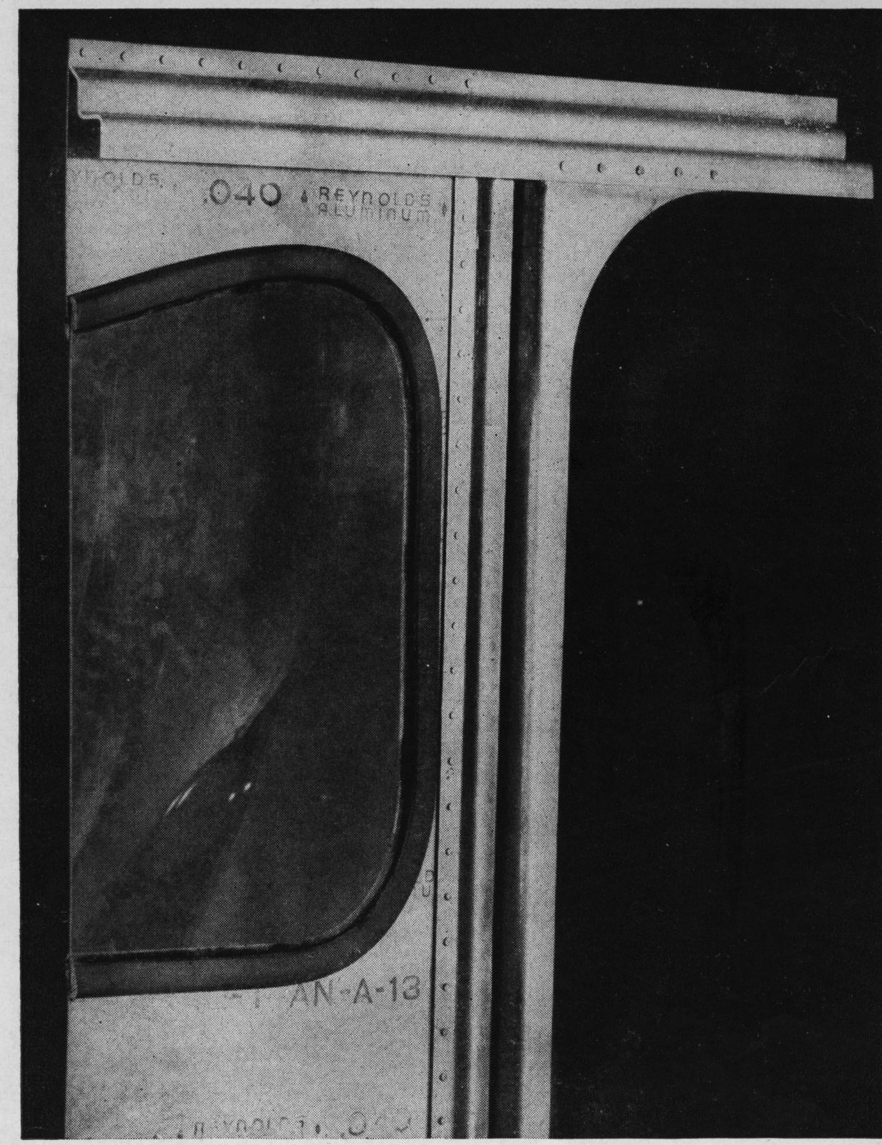


Fig. 3. A section through the cabin structure at the rear window and door (inside view, left side, looking forward). Rubber S extrusion for the retaining window is cemented to the latter and to the panel cutout margin, and serves as a weather seal, vibration damper, and trim. Combination angle- and Z-section crown bow member attaches to the side skin and door-post gusset portion.

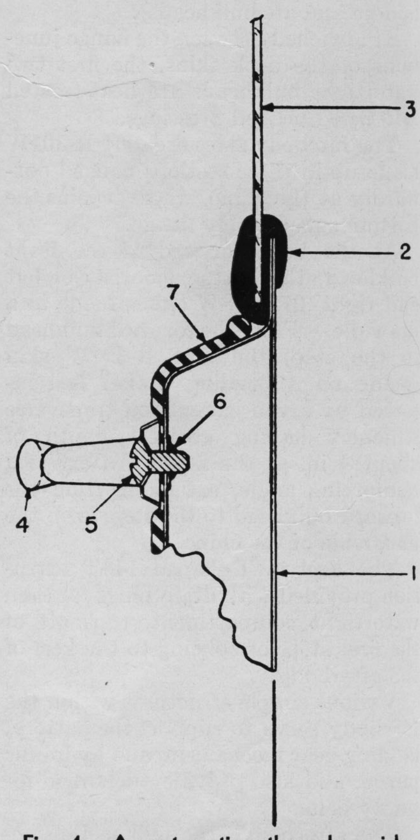


Fig. 4. A part section through a side door: (1) door skin; (2) rubber S-extrusion window retainer; (3) window; (4) pull-to handle; (5) sheet-metal screw; (6) sheet-metal nut; (7) interior trim.

The crown bow member is a rolled combination angle and Z-section unit. Doorframe uprights are identical to the crown bow frame but have a gusset portion at the top for attachment to the frame. Nesting of the crown bow and doorframe provides effective surfaces for door sealing. The two side doors and the bow doors are .032 61SW large single-piece pressings spot-welded to an .025 outer skin.

The cabin skin picks up the rivets joining the deck to sides of the hull and also is joined to the crown bow and doorframes largely by automatic riveting processes.

The crown skin is an .040 beaded pressing attached to the crown bow member with the same rivets which fasten the side skins.

Retention of each of the seven large double-curvature Lucite (Heath) cabin windows is accomplished with a simple Goodrich rubber S extrusion (3, 4) one loop being cemented to the pane and the other loop cemented to the edge of the cabin cutout margin. In addition to serving as a glass retainer, the extrusion functions as a weather seal, a vibration damper, and a decorative trim.

Standard automobile-type hardware —Cowles door handles, locks (with slight redesign), pull-to handles, and dome light—are used as far as possible, with careful selection made in regard to weight, strength, and cost, factors which also dictated the use of Tinnerman nuts and sheet-metal screws.

The back of each Reynolds seat is quickly detachable to serve as a life preserver. The front seat tracks and adjustment mechanism are American Forging & Socket standard automotive types.

Grumman F6F

The F6F Hellcat fuselage has stressed-skin semimonocoque construction (1) consisting essentially of channel section and angle-type frames and bulkheads covered with aluminum alloy skin.

The skin is stiffened longitudinally by aluminum alloy angles and channels extending the entire fuselage length. Special stiffeners are used to distribute loads at the wing center section attachment fittings (2), cockpit cutout, arrestor hook carriage track, and tail attachment fittings.

The cockpit canopy slides in a U track. At each corner of the canopy is a roller assembly which is fastened to the canopy with a screw shaft, which, in turn, is secured to the canopy and safetied with a lock nut (3).

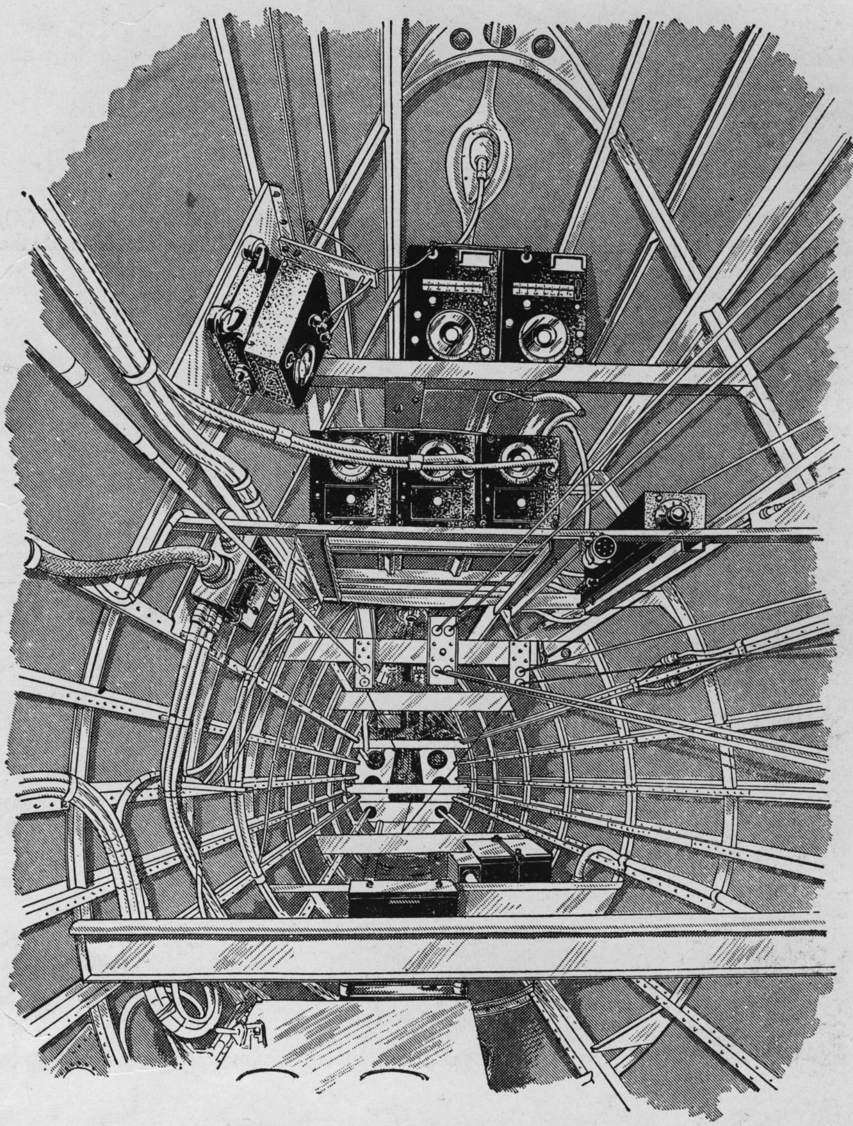


Fig. 1. Interior view of the Grumman F6F Hellcat fuselage looking aft, showing the elevator and rudder control cables and horizontal structural members for support of the radio and other equipment.

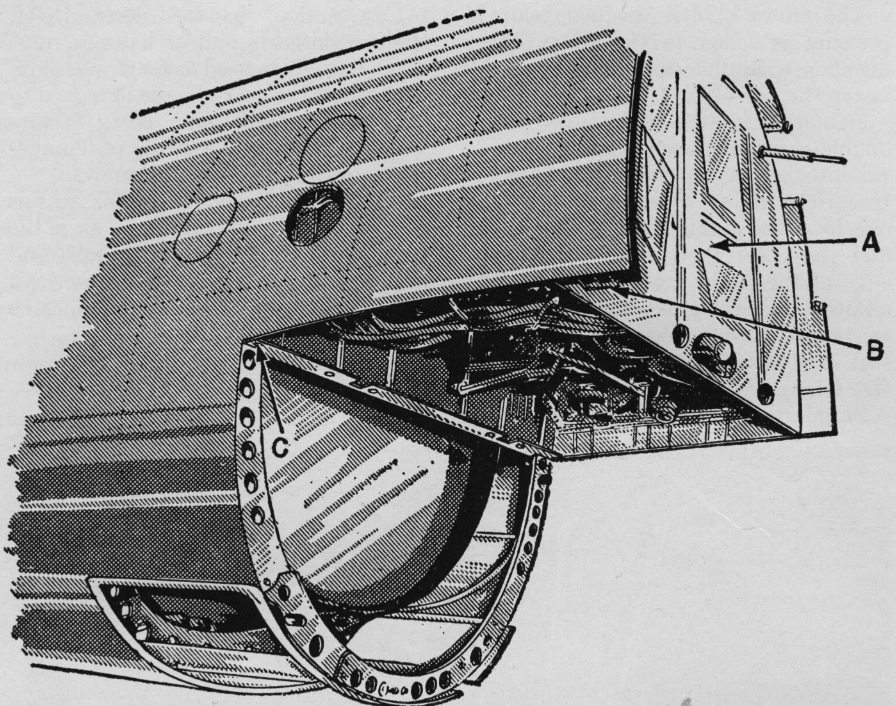


Fig. 2. The wing of the F6F attaches to the fuselage at the cutout below the fire wall (*A*), with front spar being bolted to fittings, as at (*B*), and the rear spar to fittings located inside the fuselage at points (*C*).

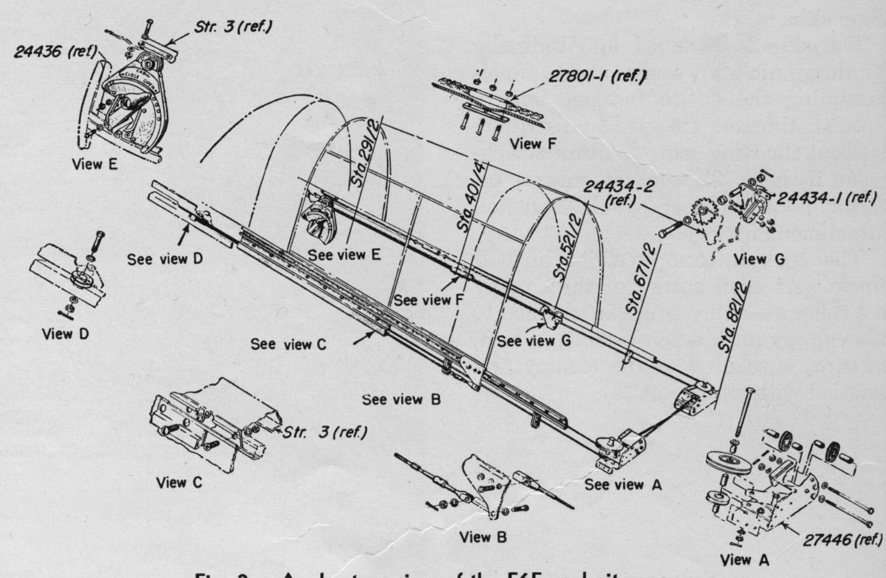


Fig. 3. A phantom view of the F6F cockpit canopy.

Hawker Tempest V

The engine mount and center fuselage constitute basically a rectangular rigidly braced tubular structure assembled with flat plate fittings and machined stampings. The rear fuselage aft of the pilot's cockpit is a monocoque structure built up of oval-shaped frames, longitudinal stringers, and a flush-riveted stressed skin. The forward portion of the fuselage is covered with detachable metal panels (1).

Bulletproof wind screen and armor are provided forward and behind the pilot. The one-piece molded blister-type canopy can be jettisoned in an emergency.

Details of the rear spar tie-through member are shown at (2).

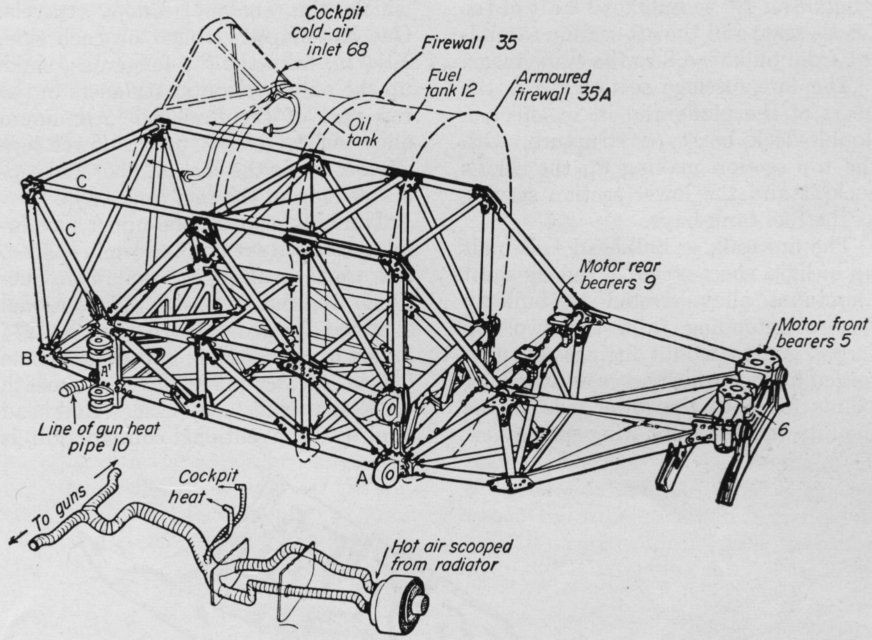


Fig. 1. Phantom view of the fore fuselage section of a Hawker Tempest V.

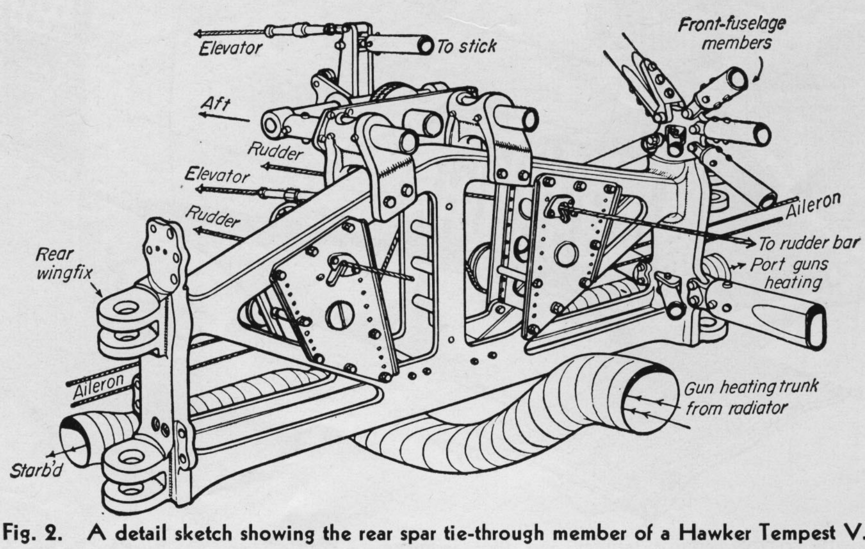


Fig. 2. A detail sketch showing the rear spar tie-through member of a Hawker Tempest V.

Focke-Wulfe FW-190

The fuselage of the FW-190 (1) consists of two major components (2): the fore section extending from the fire wall, or what the Germans called "bulkhead 1," to bulkhead 8 aft of the pilot's seat; and the aft section extending from bulkhead 8 to the empennage.

The fore fuselage section (3) is the heart of the plane and is, in effect, a double-deck box-type structure, with the top section making up the pilot's cockpit and the lower section serving as the fuel tank bays.

The fire wall, or bulkhead 1, is built up of light sheet steel backed by sheet aluminum alloy riveted to built-up flanges extending from the two top forged engine mount fittings down to forged fittings which serve as attaching points for both the lower side engine mounts and the front wing spar.

Longerons run aft from these four points to bulkhead 8, where they are spliced to lighter ones in the aft section. The top longerons are U sections, 1¾ in. wide, made up of aluminum alloy, 3/16 in. thick, and serve as tracks in which the cockpit canopy travels. One hat-shaped stringer on each side, 10½ in. from the top longerons, make up the only horizontal stiffeners in the top part of the fuselage. Aluminum alloy sheet, riveted to the lower longerons, forms the cockpit floor and separates it from the fuel tank bays.

The bulkheads in the upper fore fuselage section are not uniformly spaced, nor are they all of the same construction. Bulkhead 2, of conventional stamped flanged construction, is 12½ in. aft of bulkhead 1; bulkhead 3 some 6⅝ in. farther aft is directly beneath the front windshield base. Bulkhead 4, also of conventional construction, is 10⅝ in. farther aft. Bulkhead 5, directly under the rear end of the fixed windshield and above the rear spar fitting, is angle-shaped against the skin and extends above the floor only to the stringer. It is braced by a ¾-in. tubular section flattened at each end for riveting to the bulkhead and cockpit floor. Bulkhead 6 is an A-frame structure, the base of the fore part being 12 in. aft of bulkhead 5, the top 18½ in. farther aft. The sloping fore part is a channel section in which the pilot's adjustable seat is supported. The vertical member, set 5 in. aft of the top, is of conventional stamped, flanged construction, riveted to the fore part aft at the top by a web plate of aluminum alloy. Bulkhead 7 is of conventional construction set 12 in. aft of the rear part of No. 6, and No. 8 is a built-up stamped, flanged member extending the full depth of the fuselage and forms

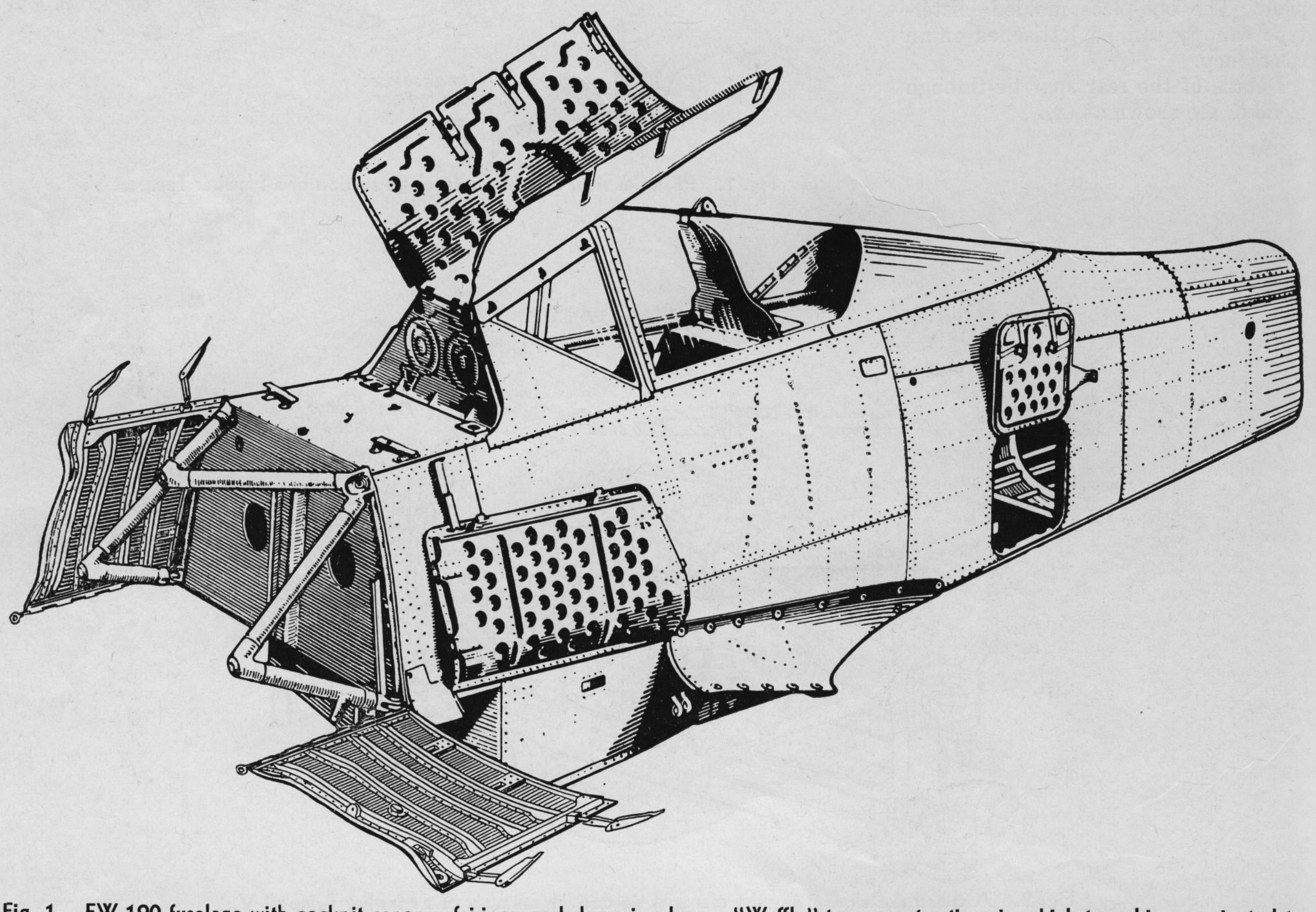


Fig. 1. FW-190 fuselage with cockpit canopy, fairings, and doors in place. "Waffle"-type construction, in which two skins are riveted together by one rivet in each dimple, brings the cowling weight to about 1.75 lb per sq ft (compared with 1.25 for American and British cowlings) but reflect German design philosophy of keeping fairings attached and in place for hurried locking. The fairings, hinged at the bottom of the engine mount, giving access to the accessory compartment, serve as work stands. The top fairing, seen folded back over the windshield, covers two 7.9-mm machine guns firing through the propeller arc; those just aft of engine-mount cowlings give access to inboard gun ammunition boxes. The door in the aft fuselage section gives access to radio, camera, and compass.

the joining point for the fore-and-aft fuselage sections.

The lower fore fuselage, or fuel bay section, has but six bulkheads. Bulkhead 1 forms the front end, being right aft of the front wing spar; No. 2, which is in reality a contour rib, is 10 in. aft and is a continuation of No. 3 from the upper section. Lower No. 3, set 5⅞ in. farther aft, is also a contour rib and joins the longeron between No. 3 and 4 of the upper section. Bulkhead 4, of built-up web construction, is the tie-through member between the rear spar fittings and separates the two fuel tank bays. Bulkhead 5 is set below the fore part of the A-frame No. 6 of the upper section and, like lower No. 6, which is set 11 in. aft, is of contour-rib type.

One belly skin panel, attached to longitudinal and transverse angle-shaped stiffeners, is attached to the lower fuselage section by nine screws along each side and five on each end, thus giving quick access to the two self-sealing fuel tanks, which are suspended from the contour rib bulkheads by heavy web straps.

On the upper fore fuselage section, immediately aft of the top engine-mount fittings, the fuselage structure is flat, forming a shelf to which are bolted mounts for the twin 7.9-mm machine guns that fire through the propeller. Back of this gun-mount shelf, the fuselage sides extend up to form the base for the windshield, the front panel of which is of 1¾-in. bulletproof glass.

At the base of this front panel is hinged the fairing to cover the guns just mentioned. This fairing, which hinges up and back for access to the guns, is of "waffle"-type construction, with the two skins being fastened together by one rivet in each inner skin dimple. Three heavy locking toggle switches—typical of those installed throughout the plane—are used on each side to hold the fairing in place.

Such heavy cowling adds what seems unnecessary weight. It is, however, in keeping with the apparent design theory; the cowling is always on the aircraft ready for locking and a quick take-off. It will stand hard wear; in fact, the side panels swinging downward around the engine mount are used as work platforms. Furthermore, in case the cowling is bent a bit, the toggles are sturdy enough to pull it into place for quick locking.

The cowling averages approximately 1.75 lb per sq ft, compared with about 1.25 for American and British planes, but the German persistence in using the type through several model numbers indicates a belief that the beatings it can take and the speed with which it can be locked into place make it worth the added weight.

The FW-190 cockpit cover (4) and its fairing are built as an integral unit. The base of the structure is a ⅝-in. tubular member bent into an inverted U at the front to fit into the windshield. The plastic glass cover is mounted between two strips of buna and a flat aluminum strip, held by screws driven into self-locking nuts in the tube. At the rear of the plastic glass a stamped, flanged aluminum A frame is set between the tube ends and is riveted to aluminum alloy fairing mounted on a ¾-in. tube extending aft. The whole

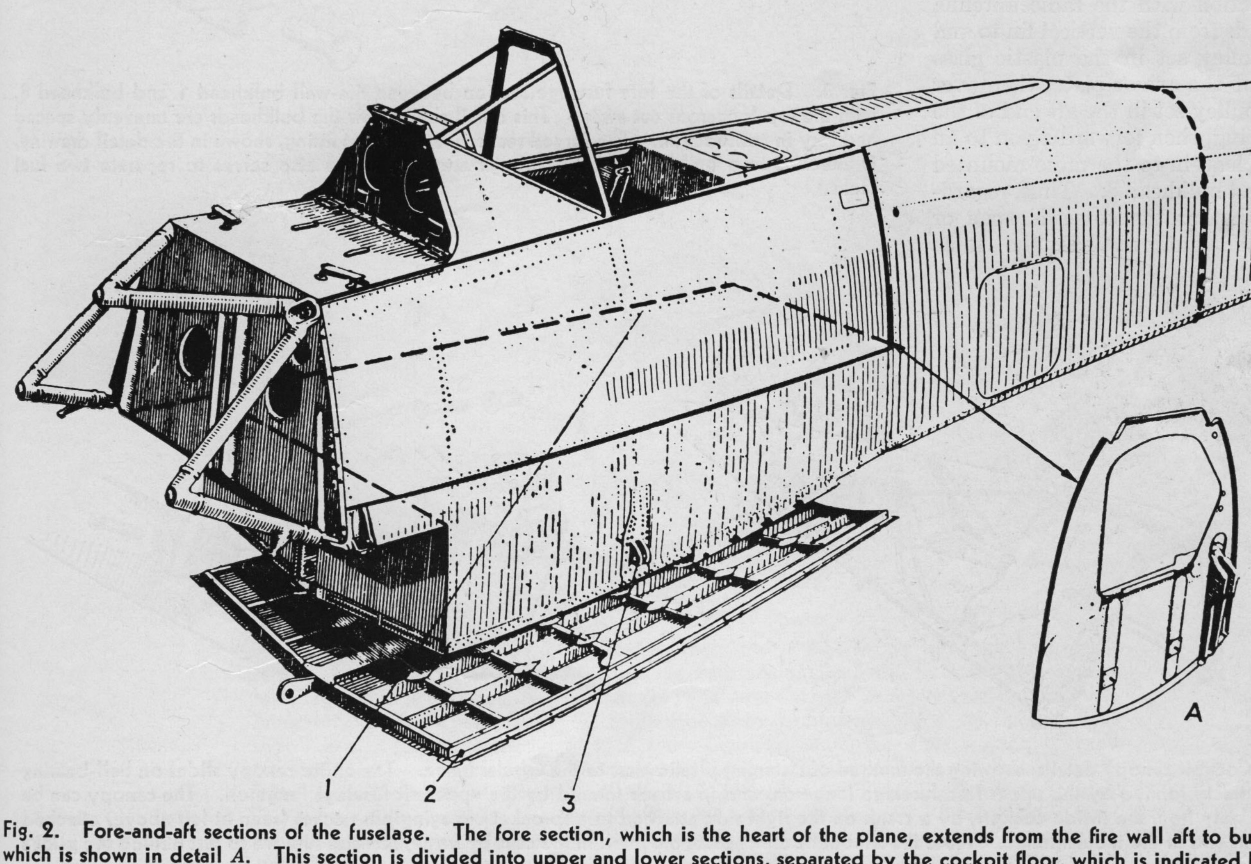


Fig. 2. Fore-and-aft sections of the fuselage. The fore section, which is the heart of the plane, extends from the fire wall aft to bulkhead 8, which is shown in detail *A*. This section is divided into upper and lower sections, separated by the cockpit floor, which is indicated by dotted lines 1. The lower section contains fuel tank bays which are covered by single skin panel 2. This is quickly detachable by loosening nine screws along each side and five in each end. The rear spar fuselage attachment fitting is shown at 3.

structure rides on three ball-bearing rollers, one on each side at the front of the plastic glass section in the top fuselage longerons, and one attached to the tube, running in a channel section (which serves as the top longeron) set in the fuselage turtle deck.

The cockpit canopy can be operated only from the inside by a crank attached to a sprocket which engages a pin ratchet attached to the front end of the tubular frame. Emergency exit can be effected by pushing down on a small handle located near the crank (5). This disengages the sprocket and then, through a series of rods and shafts, releases a latch holding the firing pin. A cartridge explodes, blowing the rear end of the canopy backward far enough to let the slip stream get under it and pull it away. The explosive charge—about the size of a 12-gauge shotgun shell—is located aft of a silhouette of ¼-in. armor plate back of the pilot's head. This armor is attached to the cockpit cover tubular member by links attached to studs welded to the armor plate.

An interesting aspect of the canopy is its connection with the radio antenna which leads from the vertical fin to and over a pulley set in the plastic glass just aft of the armor plate, then over another pulley set in the aft end of the cover fairing, then forward again to an insulated lead-in to the radio mounted just behind bulkhead 8. Thus, regardless of whether the cover is open or closed, the antenna has the same tension.

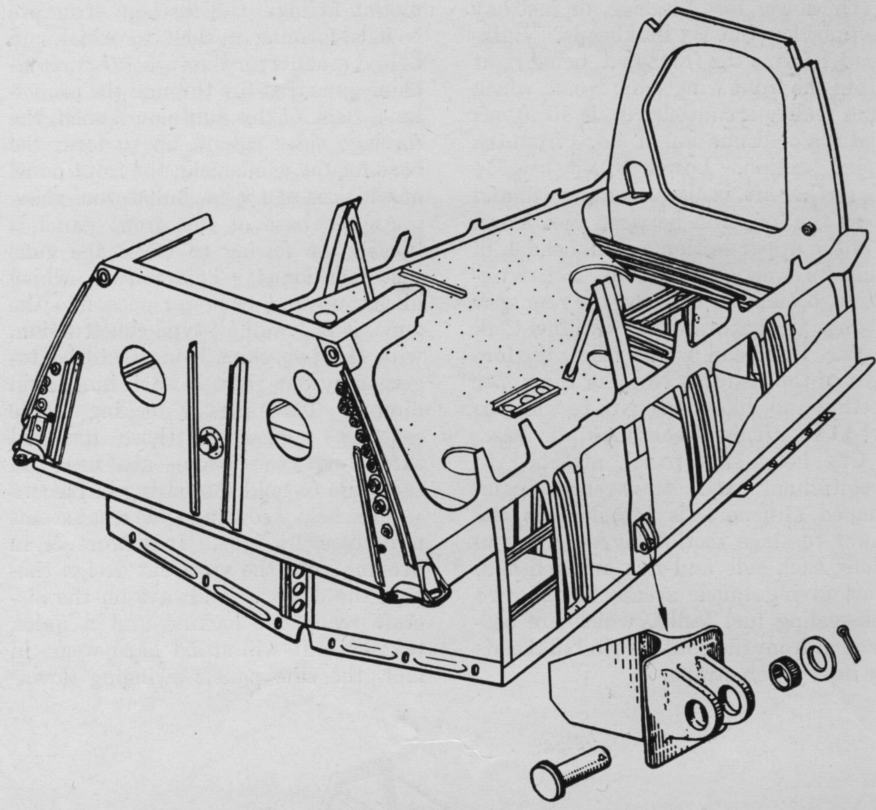


Fig. 3. Details of the fore fuselage section between fire-wall bulkhead 1 and bulkhead 8, with the top longerons cut away. This detail shows how the bulkheads are unevenly spaced and vary in construction. The forged rear spar attachment fitting, shown in the detail drawing, is attached to a build-up web tie-through member, which also serves to separate two fuel tanks.

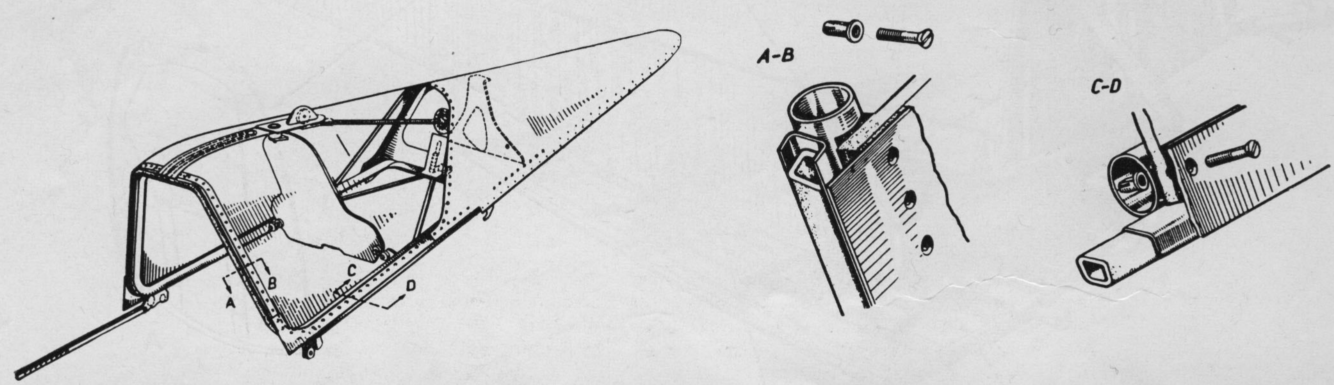


Fig. 4. Cockpit canopy details, showing the method of fastening plastic glass to the tubular frame. The entire canopy slides on ball-bearing rollers in tracks formed by the upper fore fuselage longerons and in a track formed by the upper aft fuselage longeron. The canopy can be operated only from the inside cockpit, by a crank on the right side attached to a sprocket engaging pin ratchet (seen at left above) attached to the front end of the tubular frame. Note the silhouette armor plate mounted in the canopy frame; it slides forward to just behind the pilot's head.

While the cockpit does not give the appearance of being overcrowded, there is, nevertheless, no waste space. Flight and engine instruments are arranged on two panels beneath the windshield and on horizontal panels on each side. The pilot's seat, the back of which is made of armor plate, is adjustable only up and down 4 in. and is designed for seat pack parachutes.

The aft fuselage (6), from bulkhead 8 through 14, is semimonocoque and is attached to the fore section by a double row of rivets through both skins and the flanged portion of bulkhead 8. An examination of several different craft, including more than one model, indicates that these two sections are not jig-drilled prior to mating. Apparently the two sections are brought together in a mating jig and both drilling and riveting done there, for variations in rivet locations are readily apparent. This same type of assembly is rather widely used.

Bulkheads 9 and 10 of the aft fuselage are built up in three sections, the bottom ones being heavy channel sections with flat tops to support camera installations. The upper portions of both are of conventional stamped, flanged construction, riveted together and to the bottom sections.

Bulkheads 11, 12, and 13 are of lighter construction and follow conventional practice, being built in halves and riveted together at top and bottom. Bulkhead 13 contains a cross tube for lifting the fuselage. A fabric panel is set in No. 12 to keep dust from seeping forward to the radio, camera, and master magnetic compass with its contact for control of the repeater on the instrument panel.

Bulkhead 14 is of heavy flanged construction for bolting the empennage to the aft section.

There are two upper-side channel-shaped longerons riveted to those from the fore fuselage section by 6-in. splices. These extend to aft of bulkhead 11. Extending the full length of the aft section, between bulkheads 8 and 11, a channel-shaped longeron serves to support the cockpit fairing track. Six Z-shaped stringers with rolled edges are on each side of this section of the fuselage and five in the bottom, in addition to heavy U-shaped stringers where the side and bottom sections are joined.

The aft fuselage skin, like that in the fore section, is slightly lighter than our 24ST, but no evidence of wrinkling was found in the several aircraft studied. Flush riveting is used on every surface of the plane.

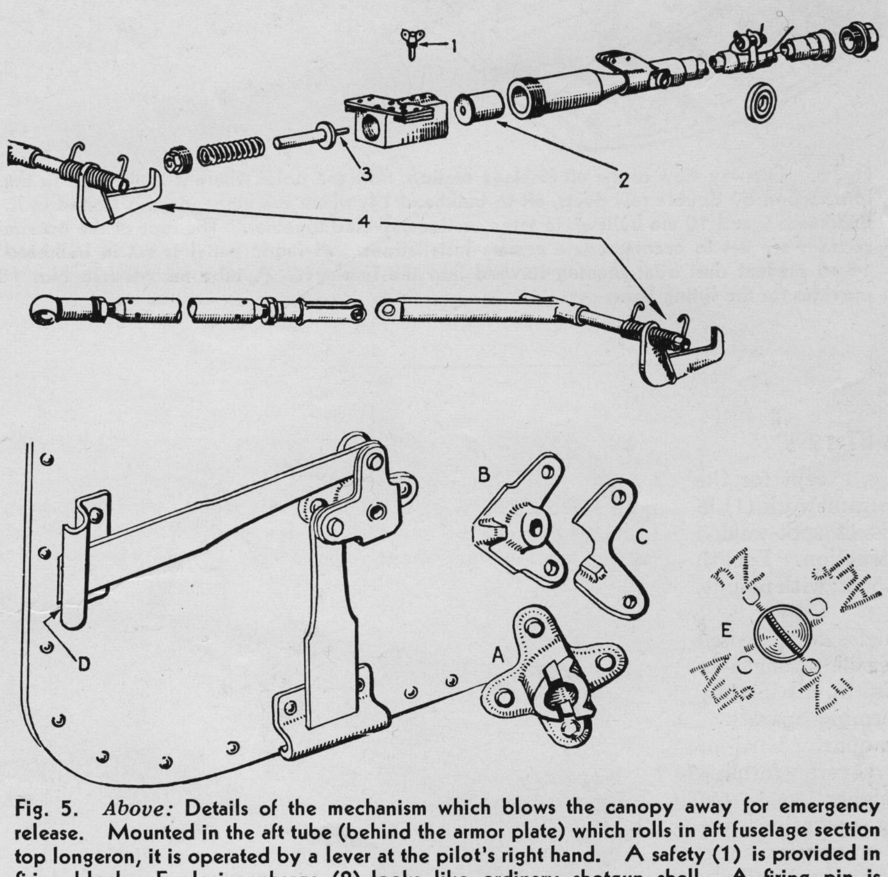


Fig. 5. *Above:* **Details of the mechanism which blows the canopy away for emergency release. Mounted in the aft tube (behind the armor plate) which rolls in aft fuselage section top longeron, it is operated by a lever at the pilot's right hand. A safety (1) is provided in firing block. Explosive charge (2) looks like ordinary shotgun shell. A firing pin is shown at (3) and a release at (4).** *Below:* **Construction of the door latches. Forged bracket** *A* **is riveted to the door. The operating bell crank is made in two parts: stop piece** *B*, **which limits throw; and latch piece** *C*, **which drops into a slot in the bracket when locked. The latch is turned with a screw driver at** *E*. **A spring keeps the screw head flush when in locked position. It must be pressed inward to release. Guide bracket** *D* **is soft enough so it can be bent with pliers to tighten the lock.**

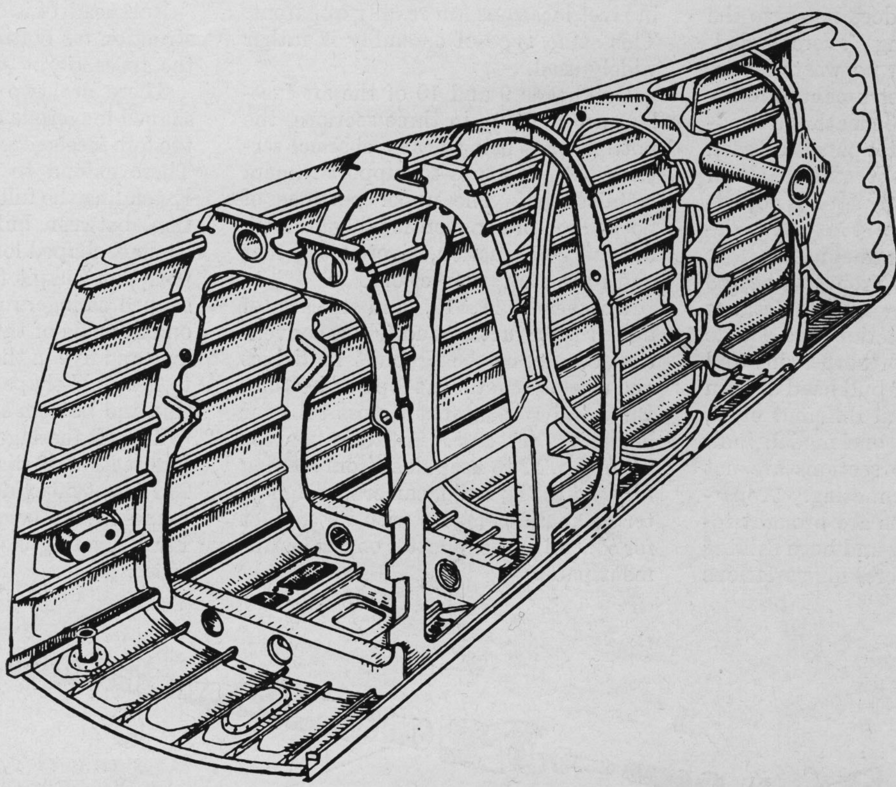


Fig. 6. Cutaway view of the aft fuselage section, from the point where it is attached to the fore section by double row rivets, aft to bulkhead 14, where the empennage is bolted to it. Bulkheads 9 and 10 are built up in three sections, riveted together. The tops of the bottom sections are flat to accommodate camera installations. A fabric panel is set in bulkhead 12 to prevent dust from seeping forward into the fuselage. A tube mounted in No. 13 provides for the lifting bar.

Fleetwings BT-12

The BT-12 fuselage, except for the chrome-moly tubular framework (1) in the cockpit region, is of spot-welded stainless-steel construction. Length without engine is 259.5 in.; with mount, 283.26 in.

The fire wall and angles are annealed and formed. The tensile strength of annealed stainless is approximately 80,000 lb; average forming operations raise it up to about a quarter hard, or 125,000 lb. More severe forming brings it up slightly higher.

For slight forming operations the material is used half or quarter hard; for severe forming it is used full-annealed. Parts which are not formed are full-hard (185,000 lb), and this is used nearly everywhere throughout the plane.

Four conical alignment studs are provided, where the engine mount bolts to the fuselage and fire wall, to aid in

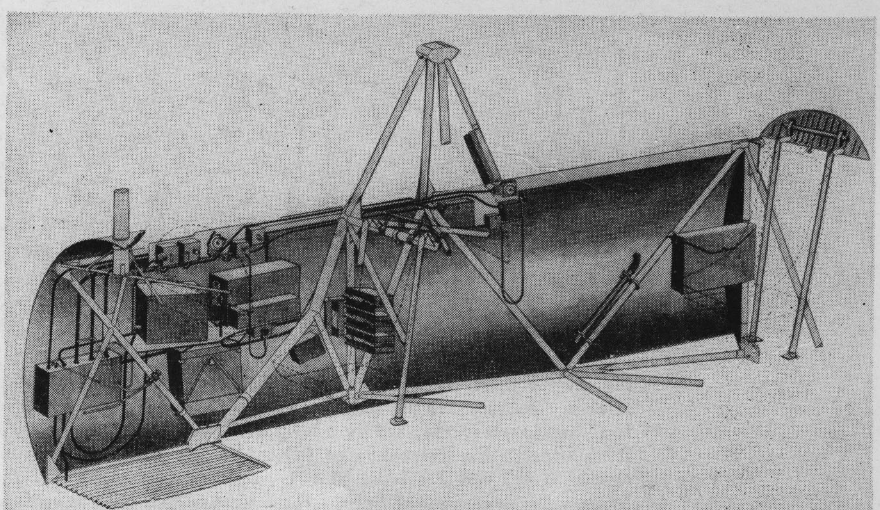


Fig. 1. Fuselage built on an arc-welded chrome-moly tube frame. The fire wall and angles are .015 stainless steel, attached by four AN5 bolts; floor, same material, .012 thick secured by six AN3 bolts. The lateral shear stresses of monocoque joints are carried by AN6 bolts; longitudinal stresses, by AN4 bolts.

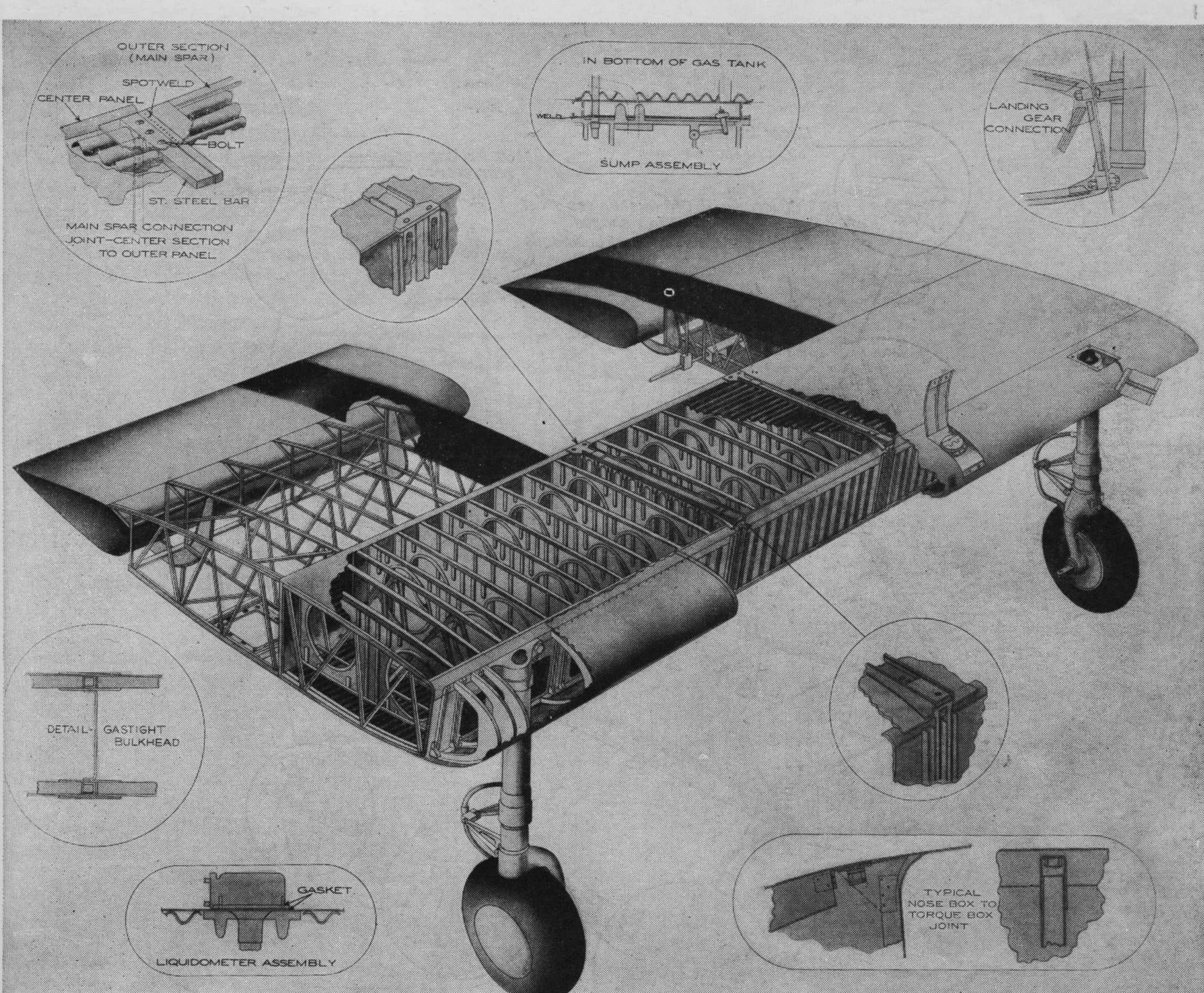


Fig. 2. Wing center section: constant chord section, NACA 23016; torque box spar .025 stainless steel with .050 capstrips; integral fuel tank. The trailing ribs are fabric-covered except for the metal walkway built into the wing and flap; the L.E. is detachable, fastened with Phillips-head screws. The front shear web is located at 8.7 per cent of the chord; the rear shear web at 40 per cent.

matching the boltholes. The tubular section is provided with six boltholes for attachment to the center wing section (2).

Bulkheads in the aft monocoque structure (3) are rubber-formed. Contrary to general belief, stainless is quite easily adaptable to this technique. The parts made in this manner for the BT-12 include, in addition to bulkheads, wing leading-edge formers and wing ribs in the D-spar region.

Upper and lower monocoque coverings are stressed-skin structural members. Except for a bolt attachment to the tubular frame, this structure is spot-welded throughout, the side truss framework being welded together as a unit in the jig.

Vertical, diagonal, and horizontal members are hat sections made on a drawbench. The upper rear shear panel is of annealed sheet, with welded-on pads to take the stabilizer spars. The tail post also is formed annealed.

Just aft of the tube structure, a shelf forms the tool compartment floor. The lower rear covering, with tail-wheel opening, is annealed stainless sheet formed under the drop hammer.

The fuselage covering is plywood, except for the engine section and fairing under the center section from the engine accessory section aft to the monocoque. This is dural sheet, better to withstand ground abrasions and knocks, as well as accumulations of oil, dirt, gas, water, etc.

Monocoque Section Weights, Pounds

Channels	34.20
Stiffeners	0.07
Angles and clips	2.09
Gussets	12.60
Bulkheads	14.84
Covering	39.46
Stringers	9.88
Longerons	11.88

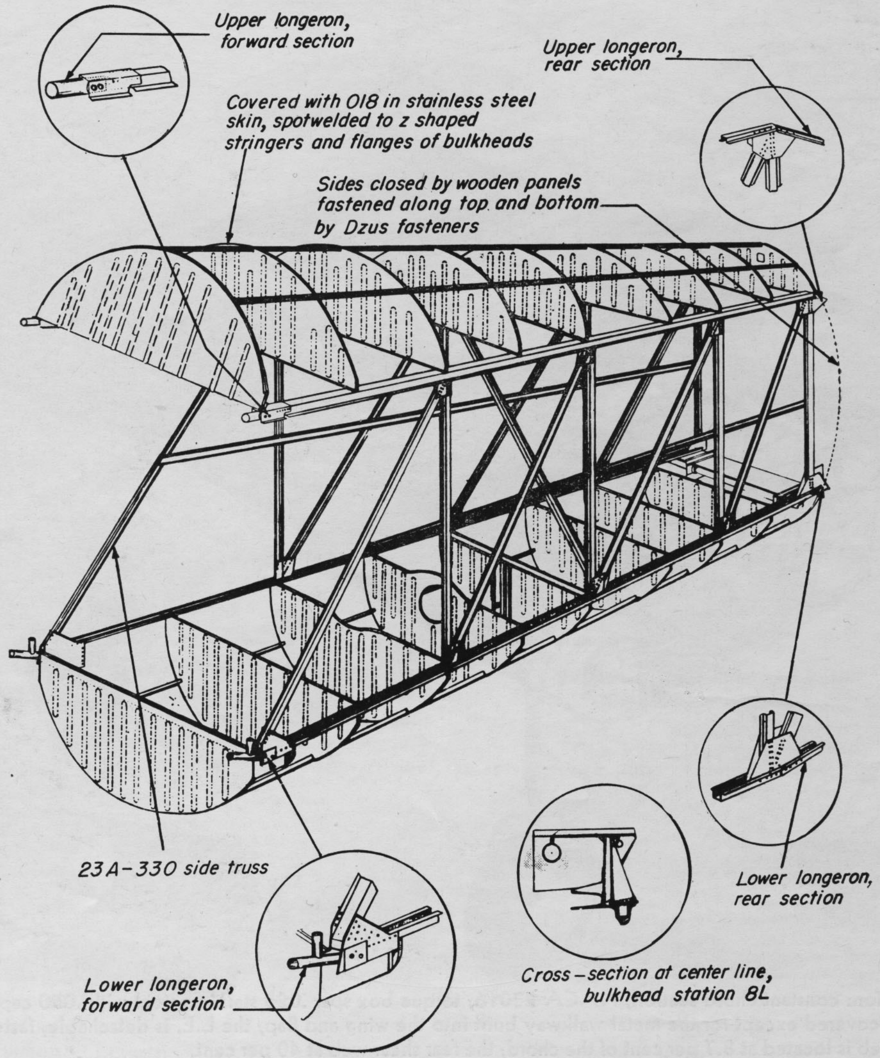


Fig. 3. Aft monocoque structure of the Fleetwings BT-12.

North American P-51

Of semimonocoque construction, the P-51 fuselage is divided into three main sections: engine mount, main and rear sections, all joined with bolts (1). With the exception of the cockpit armor fore and aft, the fuselage is entirely alclad and aluminum alloy extrusions.

The engine mount is a box beam of alclad sheet and extruded parts, so designed that the engine can be removed as a unit. The mount is attached at the fire wall with four bolts.

The main fuselage section is built around four 24ST extruded longerons, intermediate frames, alclad covering and stringers. Stainless-steel sheet and armor-plate fire wall form the forward bulkhead (2), and a turnover truss of 24ST extrusions and formed sheet protect the pilot. The upper longerons are extruded H sections which extend aft from the fire wall, tapering to a T section and terminating near the rear section. The lower longeron, H beam and U channel, extends the full length of the section.

The eight riveted and bolted assemblies which comprise the main fuselage section may be removed and replaced as units. They are firewall, turnover truss, upper deck, left and right side panel assemblies, radio shelf, web assembly, and lower section with air scoop.

Comfort and safety are given consideration in the cockpit seat design which accommodates the seat-type parachute and has a kapok back-cushion life preserver, in addition to protecting armor plate at the fire wall and seat. Heating and cooling of the cockpit also are provided.

The pilot is protected both from projectiles from the line of level flight to approximately 20 deg below it, and from fire from the engine by the combination armor-plate fire wall. This is face-hardened steel armor, except a section of stainless steel to provide room for the oil tank. Aft protection is provided by two plates of face-hardened steel behind the seat.

Protection and visibility are afforded by the windshield, rear window, and cockpit enclosure. The forward flat section of the windshield is bulletproof, five-ply laminated glass, $1\frac{1}{2}$ in. thick, slanted 31 deg from vertical. The side and upper panels of the windshield are of $\frac{3}{16}$-in. safety plate and transparent plastic. The windshield cowling extends from the lower forward end of the glass to the fire wall and down to the upper longeron.

A shroud, integral with the windshield over the instrument panel, extends aft with a circular rubber extrusion to protect the pilot. This shroud supports the windshield defroster, optical gun sight, and handholds. It also eliminates instrument glare in the windshield glass.

The cockpit enclosure consists of upper and side plastic panels, each in two sections. The one forward forms a sliding window with a locking handle. The right upper panel hinges upward; the left panel hinges downward against the fuselage. Both have locks controlled from the inside and outside. The hood is attached by four hinges on the upper longerons. An emergency release permits the enclosure to be removed or jettisoned.

Molded Lucite aft windows fit the fuselage contour and are removable for access to the radio behind the pilot. Aft of the radio, a plywood bulkhead prevents draft and keeps objects from rolling aft and fouling the controls. Nut plates at the center of the bulkhead secure oxygen bottles.

The rear fuselage section consists of two 24ST longerons, a shelf and five formers of 24ST, three solid bulkheads, and alclad skin.

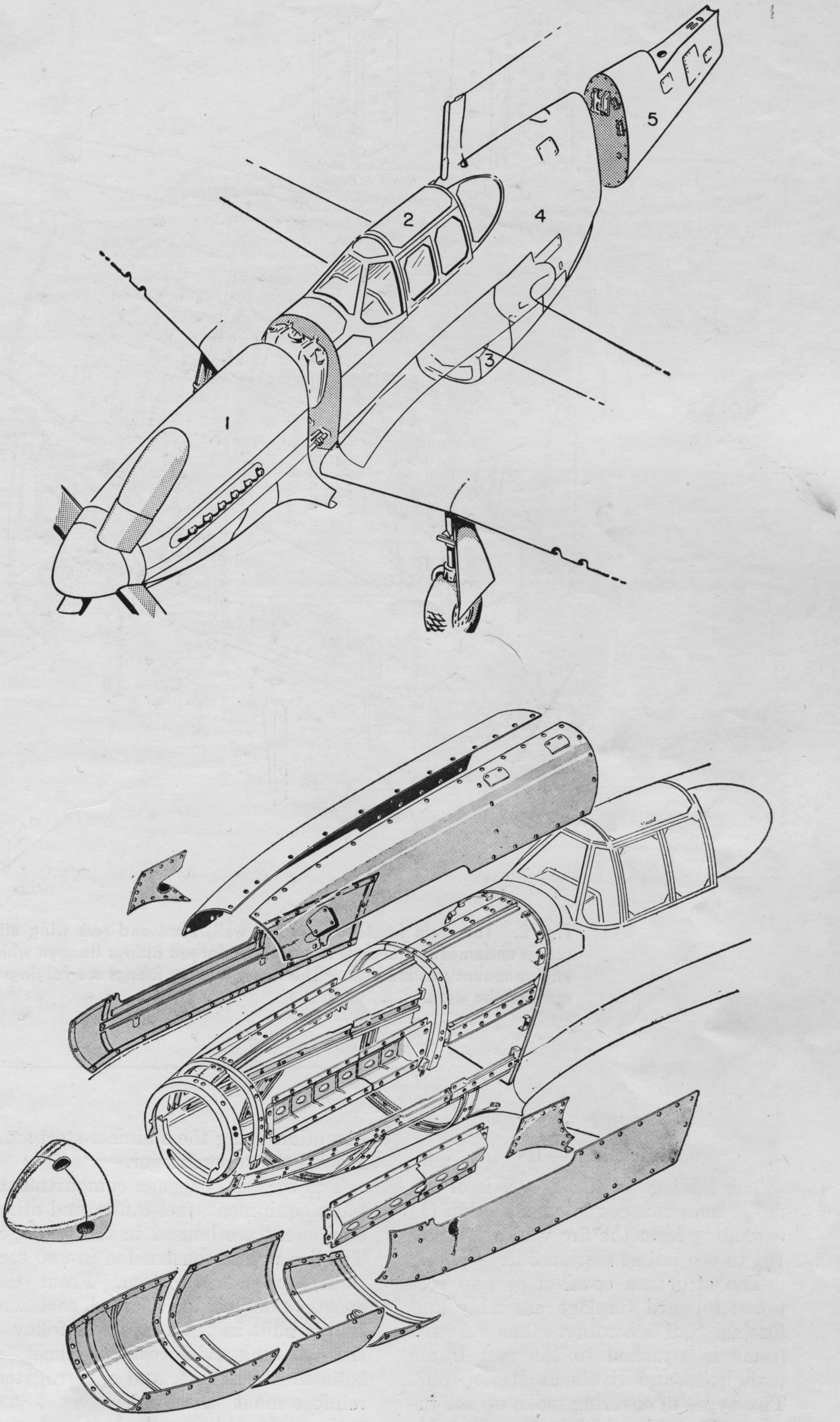


Fig. 1. *Above:* (1) Engine section; (2) cockpit enclosure; (3) radiator air scoop; (4) main fuselage section; (5) rear fuselage section. *Below:* Exploded drawing of the engine cowling and framework.

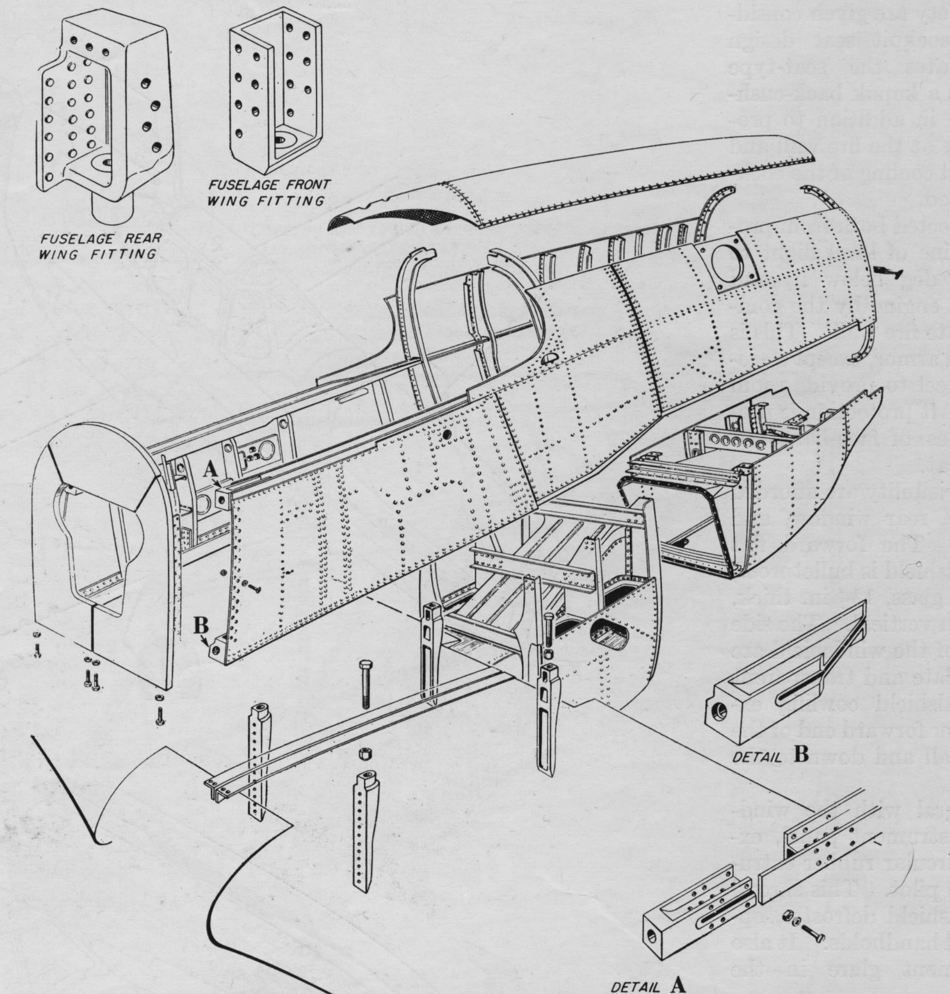


Fig. 2. The main fuselage with fire wall, front and rear wing attachment fittings, and air scoop underneath. Details *A* and *B* are forged fittings through which pass bolts holding the engine mount and fire wall. The fuselage wing fittings are forgings carrying bolts for attachment of the wings.

Republic P-47N

The fuselage of the P-47N is of all-metal semimonocoque construction (1) extending from the fire wall at station 101 to the tail at station 385.

The structure consists of two sections: forward fuselage assembly and fuselage tail assembly. The forward frame is attached to the rear frame with bolts and rivets at station 302. Two types of covering make up the fuselage skin: skin which is stressed and is part of the fuselage structure, and skin which serves as cowling to make the aircraft streamlined. For the most part, the skin is 24ST alclad, the only exception being the stainless-steel area around the supercharger.

The cockpit, baggage compartment, radio equipment, fuel tanks, and other equipment are housed in the fuselage. The fire wall is constructed in two sections, top and bottom. From the cockpit side, looking forward, each section is built in three layers as follows: the gas-tank reinforcement sheet, a stainless-steel sheet, and a corrugated reinforcement sheet all riveted together. In addition, the bottom frame has the front crosstie built into it.

The canopy (2) is a blown acrylate-base plastic panel, reinforced by cemented plastic bars along its base and front row. The plastic assembly is bolted to an aluminum alloy frame and direct contact of the plastic with the frame is avoided by the use of extruded-rubber strips. The canopy is mounted on rails with jettisoning fittings, male and female, equipped with two front rollers and a locking rail to the left side of the cockpit.

The bubble-type canopy is operated either by hand or by a motor controlled from the cockpit. The extremes of travel are limited by two limit switches mounted on the deck. The entire operating mechanism is covered by the tail of the canopy in the closed position. In order to operate the canopy, man-

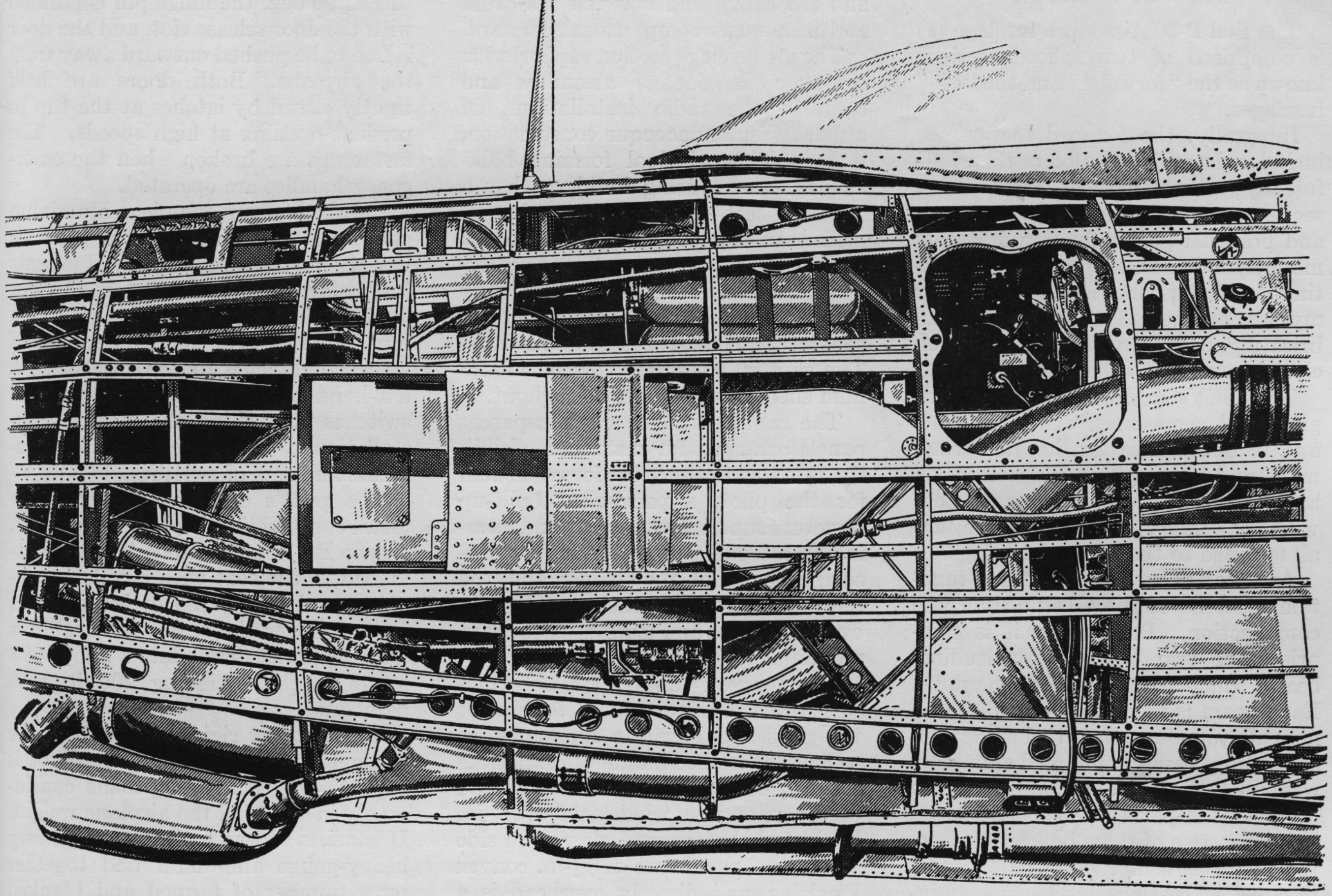


Fig. 1. Right side of the mid-section of the Republic P-47N fuselage showing the semimonocoque construction and the installation of turbo-supercharger, intercooler, and ducting.

ually, the internal or external couple release levers are pushed forward. This action releases the spring-loaded clutch and allows the canopy to slide freely on its tracks. The clutch is in the engaged position until the couple release knobs are pushed.

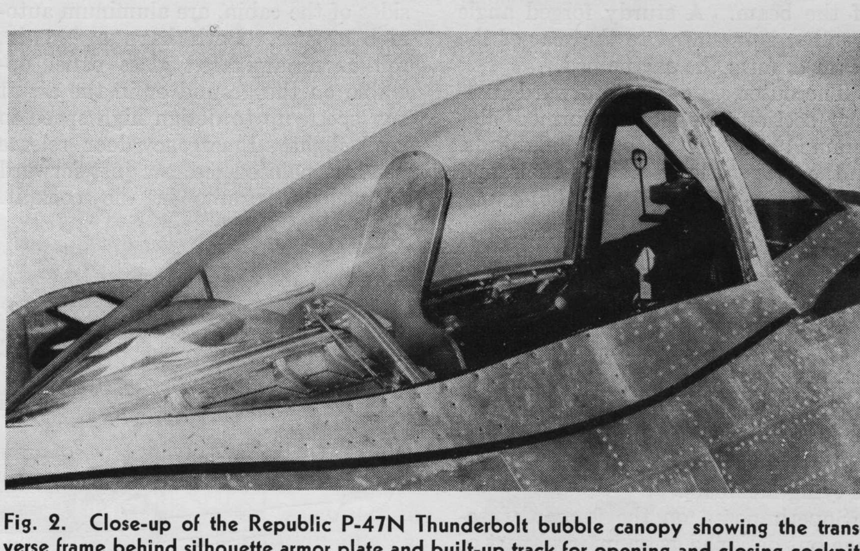


Fig. 2. Close-up of the Republic P-47N Thunderbolt bubble canopy showing the transverse frame behind silhouette armor plate and built-up track for opening and closing cockpit. The jettison unit can be seen attached to the aft face of the frame.

Bell P-39 Airacobra

The Bell P-39 Airacobra fuselage (1) is comprised of two spliced sections known as the "forward" and the "aft" fuselages.

Integrally, the forward section (2) includes the major portion of the whole fuselage, containing the center wing section, engine bed, extension shaft and propeller gear reduction assembly mounts, nose wheel attachment fittings, and supports and brackets for myriad engine accessories—fuel, lubricating, oxygen, ventilating, control, electric, and hydraulic assemblies.

The pilot's cabin, outer wings, engine, and accessories, extension shaft and reduction gearbox, heavier armament and ammunition magazines, oil and Prestone cooling systems, nose wheel assembly, and aft fuselage, are all fastened to the forward fuselage.

A section of such an impressive function must be of rugged, multipurpose construction. Principally, it is comprised of two built-up longitudinal beams which are cradle shape in profile. Each beam is made of extruded-aluminum alloy angle sections tied with virtually solid, heavily reinforced aluminum webbing. A series of formed aluminum bulkheads imparts the outboard shape. However, two of these bulkheads, located where the center wing section is tied in, are steel castings and become an integral part of this wing section.

A heavy-gauge aluminum stamped deck plate is riveted to the tops of these bulkheads and extends the full length of the beam. A sturdy forged angle member is mounted to the rear of the beam to form the engine bed.

The outer skin of the forward fuselage section consists of formed aluminum sheet riveted to the bulkheads. In the nose section are skin panels, and beneath the pilot's cabin are .051-gauge sheet. The rear panels are .032-gauge sheet.

The two longitudinal beams are maintained rigidly parallel as a self-contained unit, principally by tubular spreader bars, a forward bulkhead and former member, and the aft splicing bulkhead. In addition, the center wing section, coolant radiator supports, and pilot cabin (joined later) also act as tying members.

Superimposed on the forward fuselage but designed as an integral part of the fuselage, the pilot cabin is attached just forward of the engine compartment. Fumetight bulkheads are provided between the engine compartment and the cabin, and between the cabin and armament compartment forward.

The aft fuselage section supports the complete empennage assembly and contains the radio installation. Of ordinary semimonocoque construction, it has eight principal forming bulkheads. The splicing bulkhead has a beaded sheet web and a number of drilled stiffeners for bolts joining the aft and forward fuselages. The two forward bulkheads are tied outboard by two longitudinal bulkheads to form a compartment for the engine oil tank. The skin is .032-gauge formed aluminum sheet flush-riveted throughout.

The cabin, with its six transparent panels arranged for maximum visibility, is in two sections: the forward cabin for the pilot, a permanent built-up structure superimposed upon and forming an integral part of the forward fuselage ahead of the engine; and the removable aft cabin enclosure directly over the engine and joining the forward section at the turnover beam.

The forward cabin section is comprised of drawn aluminum frames for the glass and Plexiglas enclosures, as well as the formed aluminum skin sides forward of the door. Directly ahead of the pilot is a windshield of $\frac{1}{4}$-in. laminated shatterproof glass; two side windshield panels are of $\frac{1}{4}$-in. convex Plexiglas, and directly overhead is a $\frac{5}{32}$-in. Plexiglas panel formed to the cabin contour. All panels are set in rubber channel retainer strips.

The doors (3), located on both sides of the cabin, are aluminum automobile type. Both have a $\frac{21}{64}$-in. roll-down laminated glass panel operable on the ground or in the air at any speed up to design high speed in level flight. Emergency-door release handles, painted red, are just forward of each doorframe in the cockpit. When the handle is pulled out and turned 90 deg, the hinge pin is parallel with the door release slot, and the door is free to be pushed outward away from the airplane. Both doors are held tightly closed by latches at the top to prevent opening at high speeds. The fastenings are broken when the emergency handles are operated.

Constructed of one-piece aluminum alloy, the main instrument panel is flexibly mounted on three Lord mounts just below the center windshield. An auxiliary instrument panel is set to the immediate right of the main panel and attached directly to the fuselage. A left-hand panel consists principally of switches controlling the electrical installations. There are some 36 instruments and sets of switches.

The pilot's seat is of bucket-type metal construction, and nonadjustable. A type B-11 Sutton safety harness is attached to the seat with a roller mechanism and is released or locked by a control under the seat. The cabin is designed to accommodate a pilot 5 ft 8 in. in height, weighing 200 lb with parachute.

Of extremely rigid construction, the turnover bulkhead behind the pilot is capable of withstanding loads considerably in excess of the airplane weight. It consists of two main beams of very heavy-gauge aluminum tied together by a number of formed and blanked bulkhead sections and heavy-gauge formed aluminum skin flush-riveted to the beams and bulkheads. Additional strength is provided by crossed streamline wire bracing tightened by turnbuckles running from the top of each side of the assembly to the bottom of the other side.

The aft cabin is a shallow streamline structure conforming to the fuselage contours. It is enclosed by two convex panels of $\frac{5}{32}$-in. Plexiglas and consists

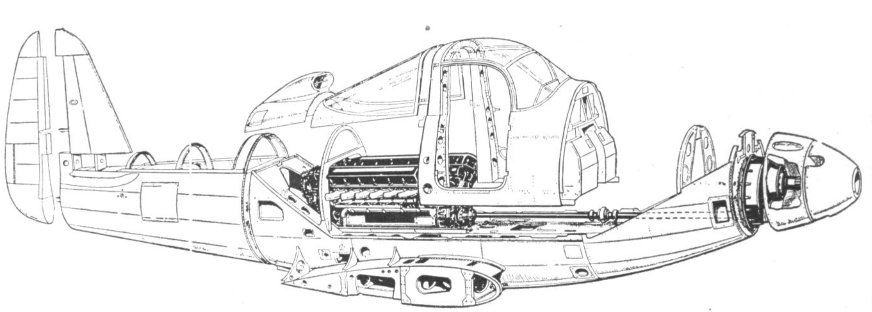


Fig. 1. Cutaway drawing showing structural details of the Bell P-39 Airacobra.

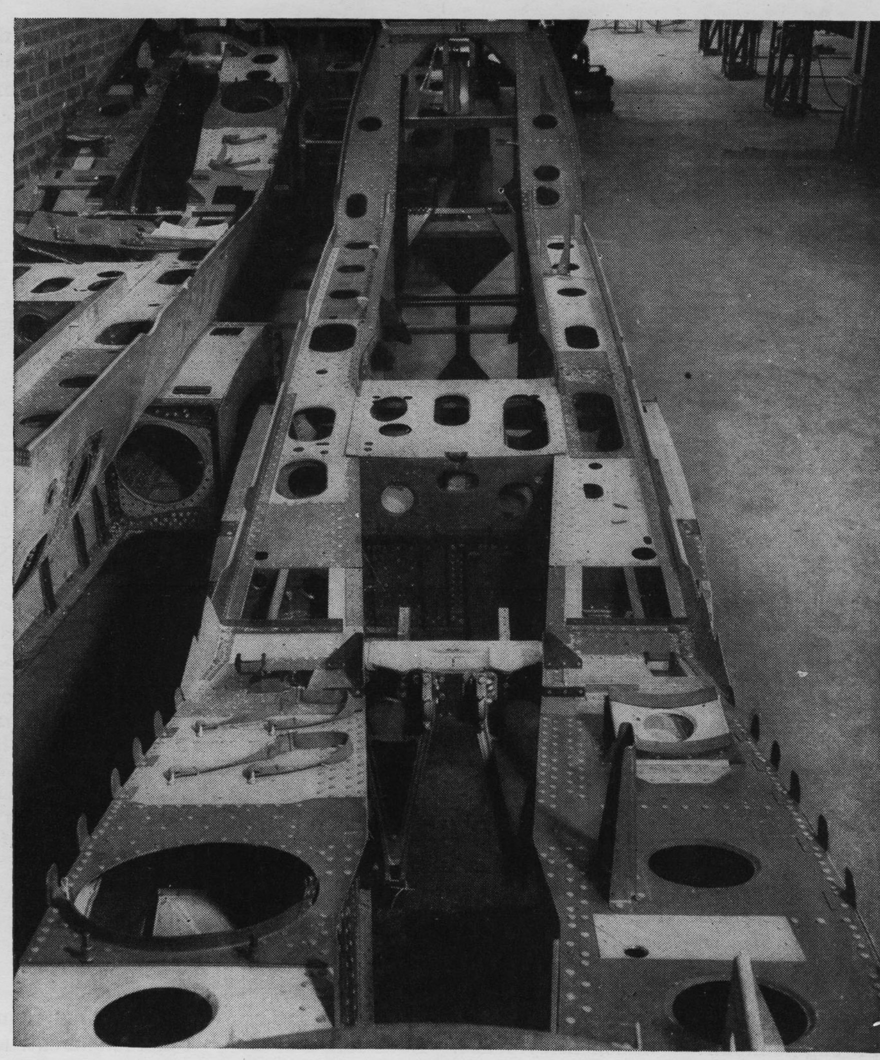


Fig. 2. Looking rearward along the two parallel longitudinal beams making up the forward fuselage structure. The engine is located on the bed to the rear, and the pilot cabin is superimposed ahead of the engine location. The wing center section becomes an integral part of the fuselage.

of channel formers and a beaded aluminum deck plate for housing a portion of the radio installation.

This removable aft cabin joins the forward section at the turnover beam.

Cabin heating is provided by two 3-in. metal tubes which take hot air from directly behind the Prestone radiator and expel it to two ducts on the cabin floor beneath the pilot's seat. The hot-air duct extends between the engine and fuselage longitudinal beams. Cool air is supplied to the cabin by two ducts which take air from the Prestone cooling duct just forward of the radiator. The same ducts emitting the hot air also transmit the cool air.

The selection of hot and cold or mixed air is controlled by two butterfly flaps, one of which is located on each duct Y at the union of each hot- and cold-air duct. Two L-shaped handles, adjacent to each other on the floor to the right of the pilot seat, operate the butterfly flaps.

Air is exhausted from the cabin through ducts over the rudder pedal well. These ducts lead to the cannon and .50-caliber machine guns. Air supply to the cabin is constant and only the temperature may be regulated. Because of this, there is greater air pressure in the cabin than in the gun compartment, thus preventing fumes from the latter entering the cabin.

The two flexible heater tubes emerg-

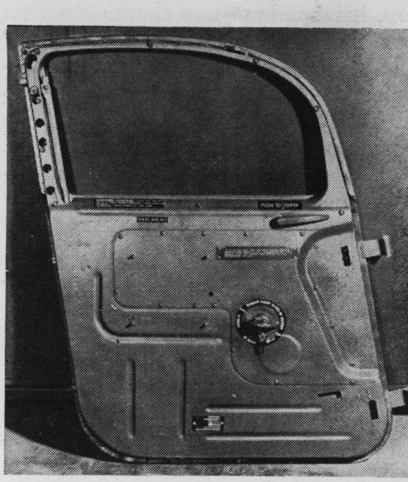


Fig. 3. The cabin door is automobile type with roll-down glass panels.

ing into the gun compartment extend upward and join together at a duct attached to the pan and feed chute assembly of the .50-caliber machine guns. This duct has two flanged outlets which heat the guns. The forward end of the duct extends downward and to the left, tapering out fan-shaped for heating the cannon installation.

Zeke 32 (Hamp)

Built in two sections: a semimonocoque fore section extending from the fire wall 103 in. aft to former *J*, (1), which is just aft of the wing trailing edge and just forward of the cockpit canopy fairing; and the aft section of full monocoque extending from former *K*, which is butt-bolted to former *J*, but of lighter material, to former *V*, a distance of 144 in.

The fore section is built integrally with the wing and, in fact, is not structurally complete until riveted to the top wing skin, which forms the cockpit floor.

The principal fore-and-aft members are four longerons extending aft from the engine mount to former *H*, just forward of the T.E. of the wing. The top two longerons are fairly heavy aluminum alloy hat-section members; the lower two are channel sections riveted to the upper wing skin and bolted to the spars. These longerons are flattened to accommodate formers *B* through *H*. Three ¼-in. hat-shaped stringers are spaced evenly between the longerons and extend to former *J*.

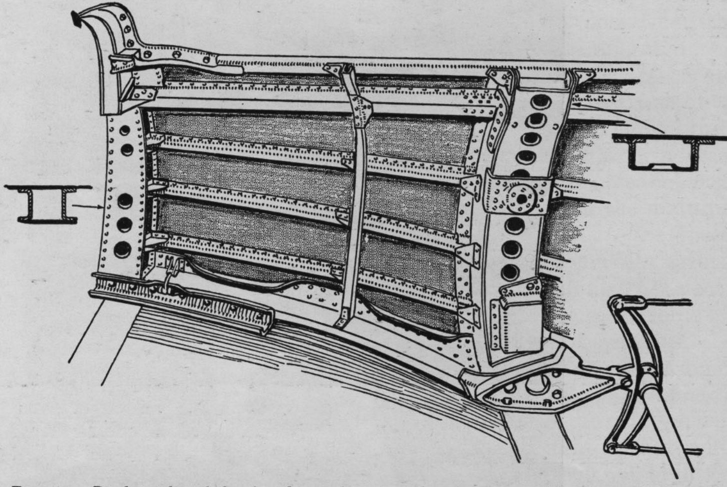


Fig. 1. Right side of the fuselage showing the structure of formers *D* and *G*, built-up box structures mounted on the front and rear spars, respectively. The cockpit canopy rail extrusion forms the top edge. A heavy longeron just below it extends from the base of the windshield to former *J*. The longeron at the bottom of the cockpit side follows the contour of the top wing skin which is the cockpit floor. Brackets for elevator control are attached to former *G* and the rear spar. Note that the pivot pin is 1½ in. ahead of the torque tube axis.

Former *A*, to which is screwed the light sheet-steel fire wall, is a ring bulkhead containing the four engine mount bolts, while formers *C* and *D* shape the skin around the fuselage fuel tank. Former *D* extends up from the front spar to the base of the windshield. Tapering to a width of 1½ in. at the top, it is made of two channels with a box facing and has varying sizes of flanged lightening holes. A heavy tubular tie-through member at the top supports two 7.7-mm machine-gun breeches and the top instrument panel. A similar, but smaller diameter, tubular tie-through member attaches to the bottom of the instrument panel and the middle of the three stringers.

Formers *E* and *F* are lightweight hat-shaped contour frames riveted to the longerons and stringers. Former *G*, a built-up hat-shaped structure with lightening holes along the inner face, extends up from the rear spar to the top longerons.

Former *H*, some 6½ in. aft, is a full contour built-up member extending from the lower longerons up through the fuselage top to form the turnover truss. Lightening holes, again, are much in evidence. Both fore-and-aft sides have some as large as 4 in. near the center, with another row of 1-in. diameter holes near the flange face which, in turn, has 1-in. holes spaced ½ in. apart. This member supports the pilot's seat by means of a torque tube to which two arms are riveted. The cutout in former *H* forms the only access to the accessory compartment (2), with entrance being gained by loosening two pins from the back support of the pilot's seat, and tilting it forward.

Former *I* is a light hat-section frame. Former *J* is made up of 1- by ¾- by ⅛-in. extruded angle sections with 80 holes for $^3/_{16}$-in. bolts spaced 1½ in. apart forming a butt joint for joining to the aft fuselage section.

The fixed windshield consists of three flat plates of glass, none of which is bulletproof. The cockpit canopy likewise uses ordinary glass, all flat plate except for the segments in the curved top, the edges of which are beveled and rubber-mounted. The light aluminum and plywood frame slides 27 in. on six rollers in an extruded track section and can be locked in four positions by a spring-loaded pin sliding down into holes in the top of the track. Locking is accomplished either in or out of the cockpit by a handle set near the top of the forward part on the left side. No emergency jettisoning arrangement is provided.

The cockpit arrangement in general follows conventional practice except for size. While big enough for Japanese, a typical American pilot in full flying gear would be pretty well jammed in. The top instrument panel includes the gun sight at the top, with the breeches of the two 7.7-mm machine guns just below on either side, and the artificial horizon and bank-and-turn indicator centered.

Also on this panel, mounted on Lord-type vibration absorbers, are the usual flight and engine instruments and switches. A panel on the pilot's left contains the throttle and gun quadrant, fuel tank selectors, hydraulic system

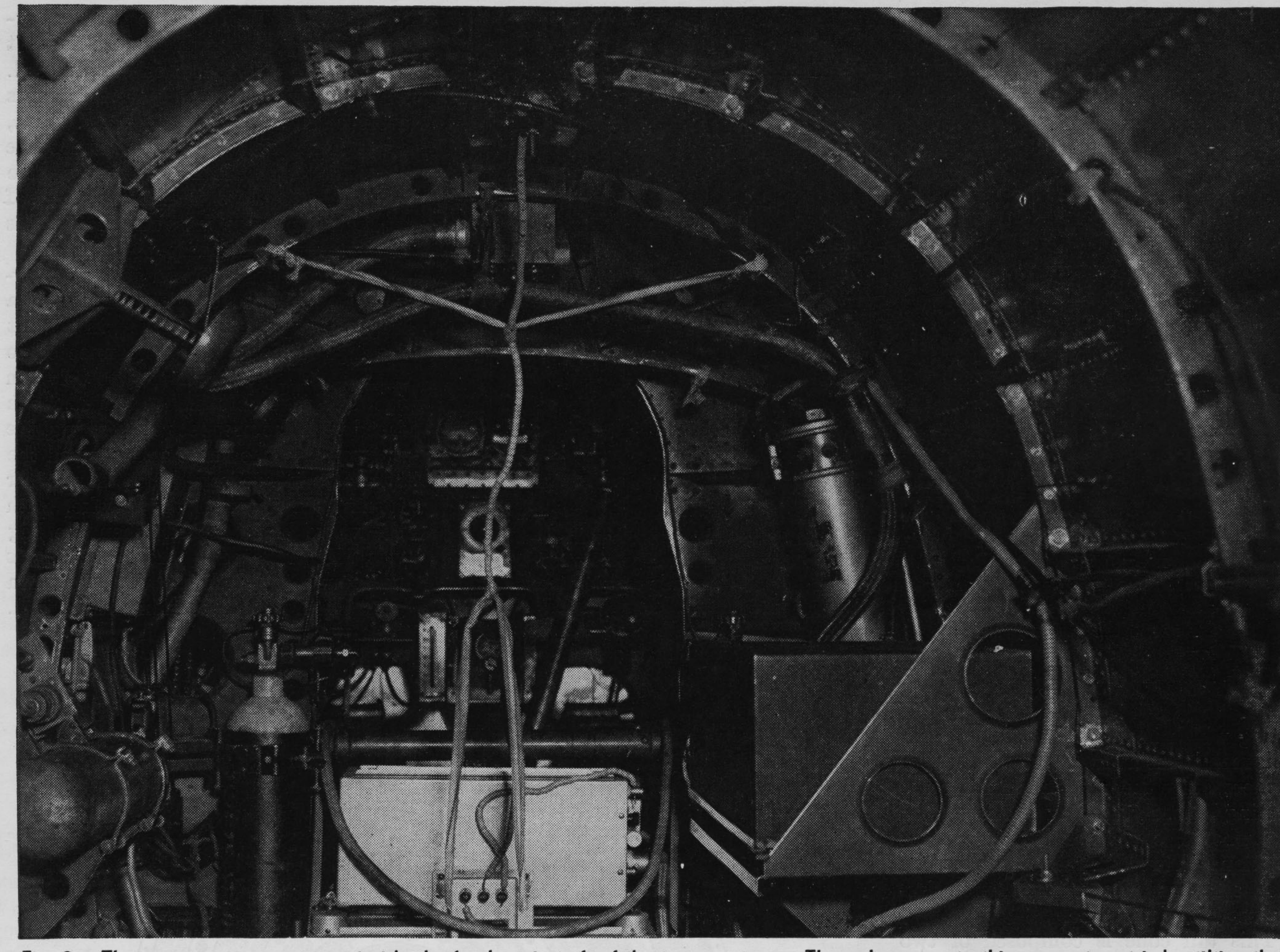


Fig. 2. The accessory compartment inside the fuselage just aft of the turnover truss. The only access to this compartment is by tilting the pilot's seat forward and crawling through an opening in the turnover truss. Note how the brackets are set between spanwise and lengthwise members to give additional strength without increasing weight. Mushroom heads to protect the flotation bag are at the upper left.

controls, electric switch box, etc. An unusual item on this panel is a parachute static line hook.

The panel on the right side contains mechanical cowl flap controls; radio and landing gear controls, arrestor hook release; fresh-air tube, etc. Cockpit heating equipment apparently is not standard, but some planes have electric heaters around the air intake.

Also on this side is the lever for raising or lowering the pilot's seat which is adjustable only up or down. The lever has a push button like an automobile emergency brake, but no ratchet—merely a square-tooth quadrant. A shock cord bungee passing over two pulleys on the turnover truss pulls the supporting arms upward.

The cockpit entrance is from the left side via three retracting steps and two handgrips, all of which are spring-loaded and released by very smooth-fitting flush push bottons. One button releases the lower step, which drops down out of the fuselage just aft of the T.E., and one comes out the fuselage side just above the wing. Individual buttons are used for the other steps and handgrips. The steps and handles behind the overturn bulkhead have 2½ in. diameter .024 aluminum mushroom-shaped heads on the inside to prevent puncturing the fuselage flotation gear (3).

Throughout the cockpit, wherever possible, brackets or supports are located between the spanwise and lengthwise members so as to give a little additional strength.

The full monocoque aft section of the fuselage, as mentioned previously, extends from former *K* to *V* (4).

All except *L* and *N* are full circumference, spaced 16 in. apart, and are *J* section. Those near the front end are 1½ in. deep. These are built up in three sections, lap-jointed, and riveted. Gauges vary from .048 for the front lower sections, through .035 at the top, to .018 for those near the aft end.

The formers all have standard cutouts for the stringers, with ¾-in. lightening holes between the stringers.

There are 22 Z-shaped ½-in.-deep stringers in the aft fuselage section, spaced approximately 6 in. apart at the fore end. All have four right-angle clips for attachment to the frames. A built-up hat-section longeron extends along the bottom from former *K* to aft of former *S*, where the arrestor gear hook attachment is made.

Formers *S* and *U* carry tubes for stabilizer spar attachments and elevator trim tab control equipment. Former *V* is built up of a channel section frame supporting the fin post, bottom rudder hinge, and the tail-wheel drag yoke

aft section. The fuselage is flush-riveted throughout, with all fore-and-aft joints being lapped, others butted. Also, throughout the plane, small rivets are used, few being larger than ⅛ in., some being only $\frac{1}{32}$ in. Despite the rivet sizes, there is no evidence on the craft examined to indicate a lack of strength, nor were there any indications of sloppy workmanship.

The principal flotation gear for over-water operations consists simply of a large waterproof canvas bag in the aft fuselage section. This is connected to a tube leading to a barrel-type valve on the cockpit's left side. Thus, when faced with the prospect of ditching, the pilot opened the valve and allowed the bag to be inflated by the pressure of air rushing in through the intake, with the valve being closed when the bag was fully inflated. The main bag is not connected with the wing flotation gear (covered in discussion of the wing).

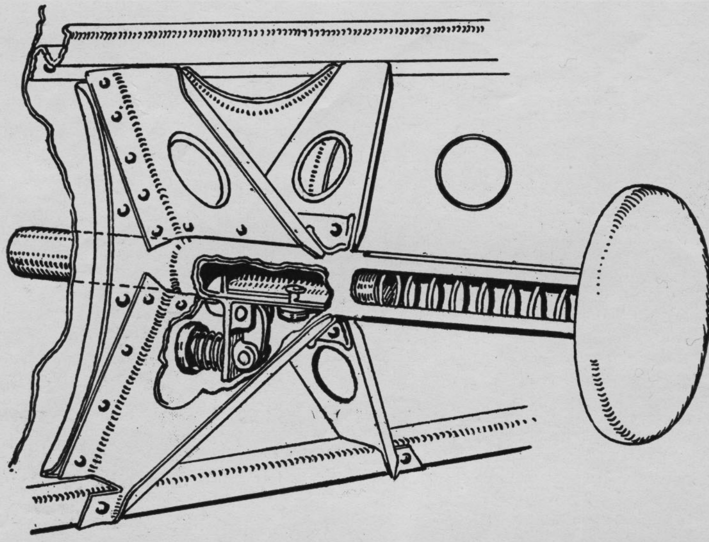


Fig. 3. A cutaway view showing the construction of the upper handhold support bracket and mushroom head for protecting the fuselage flotation gear. The tube handle is slotted and pushed out by a small spring in the skeleton tube, a section of which is shown above the tube. A button, flush with the fuselage skin, releases a latch which holds the handle tube inside the fuselage. A rivet projects in the slot to prevent the handle from flying off when released.

fitting which is riveted to the bottom. This member is not parallel to the other formers, since the bottom is farther aft, putting it nearly vertical to the ground line when the plane is in three-point position. Three stamped brackets on each side serve to anchor quick fasteners on the tail cone.

This tail cone is composed of two stamped alloy sheets with two J- and two L-section stiffeners riveted inside each half. Small fairings extending out to the elevator also serve as stiffeners.

The cone has a depth of 20 in. where it attaches to the fuselage. It is 31¼ in. long at the top and 36 in. at the bottom, where a formation light fits into the aft end. Three quick fasteners and 10 screws on each side hold it into place, and a canvas dust catcher is screwed on and attached to the tail-wheel drag yoke by a piano hinge. A bayonet plug connection is provided for the formation light.

Removal of the tail cone exposes the tail wheel and combination retracting unit-oleo shock, one of the few features of the Zeke which would arouse any enthusiasm in a maintenance man.

The skin on both the fore and the aft fuselage sections is of lighter alloy than is used customarily on occidental planes. That on the fore fuselage is .048 gauge on the lower portion and .035 near the top, and .018 for all the

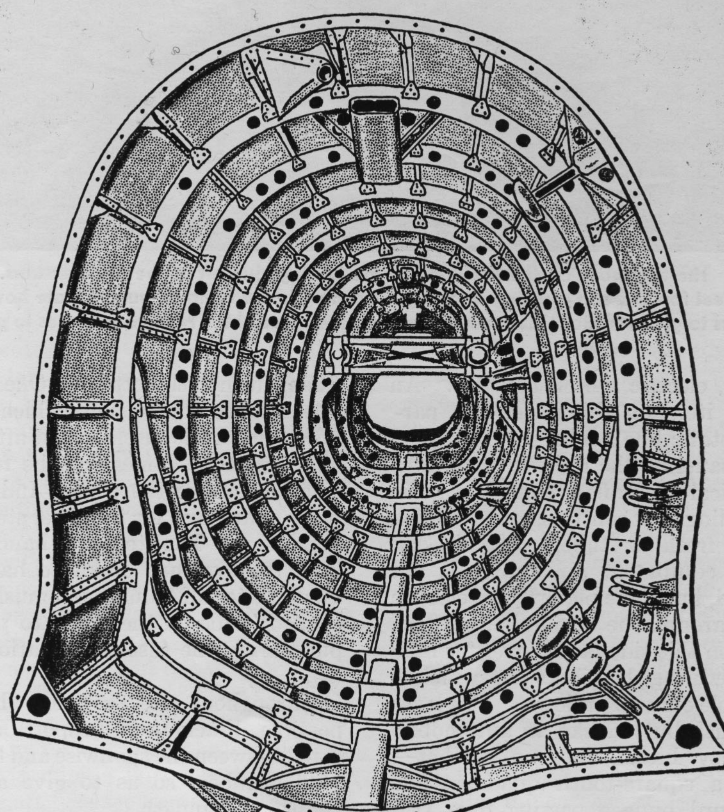


Fig. 4. Interior view of the aft fuselage section from former *K*, or mating flange. Mushroom-shaped units at the top and bottom foreground cover retractable handholds and step, respectively, to prevent puncturing the fuselage flotation gear. Rudder control cables run through protecting covers (right) for the same reason. The cross tubes in the background support stabilizer spars and elevator trim tab controls.

The arrestor gear, which appears to be left on the plane whether or not it is to operate from a carrier, is built up of a T extrusion with the forged hook riveted on. Extension and retraction are by means of a flexible cable running from a crank set in the right side of the cockpit. This handle incorporates its own lock, for the handle can be pivoted in toward the axle and locked into teeth extending out from the hub.

Ryan FR-1

The FR-1 fuselage is divided into fore-and-aft sections, the forebody (2) being of semimonocoque structure of elliptical shape above the horizontal center line and circular below.

The jettisonable cockpit enclosure is designed like an airfoil which is compressed in length.

To facilitate access to the turbojet power plant, a General Electric I-16 engine, the fuselage can be "broken" at the former at the end of the fore section structure. The fuselage sections are joined at four points. There are quick-disconnect multiple electric connections to facilitate servicing.

The aft section is a circular monocoque structure with tail surfaces so mounted that there is no interference with the exhaust from the jet power plant (1).

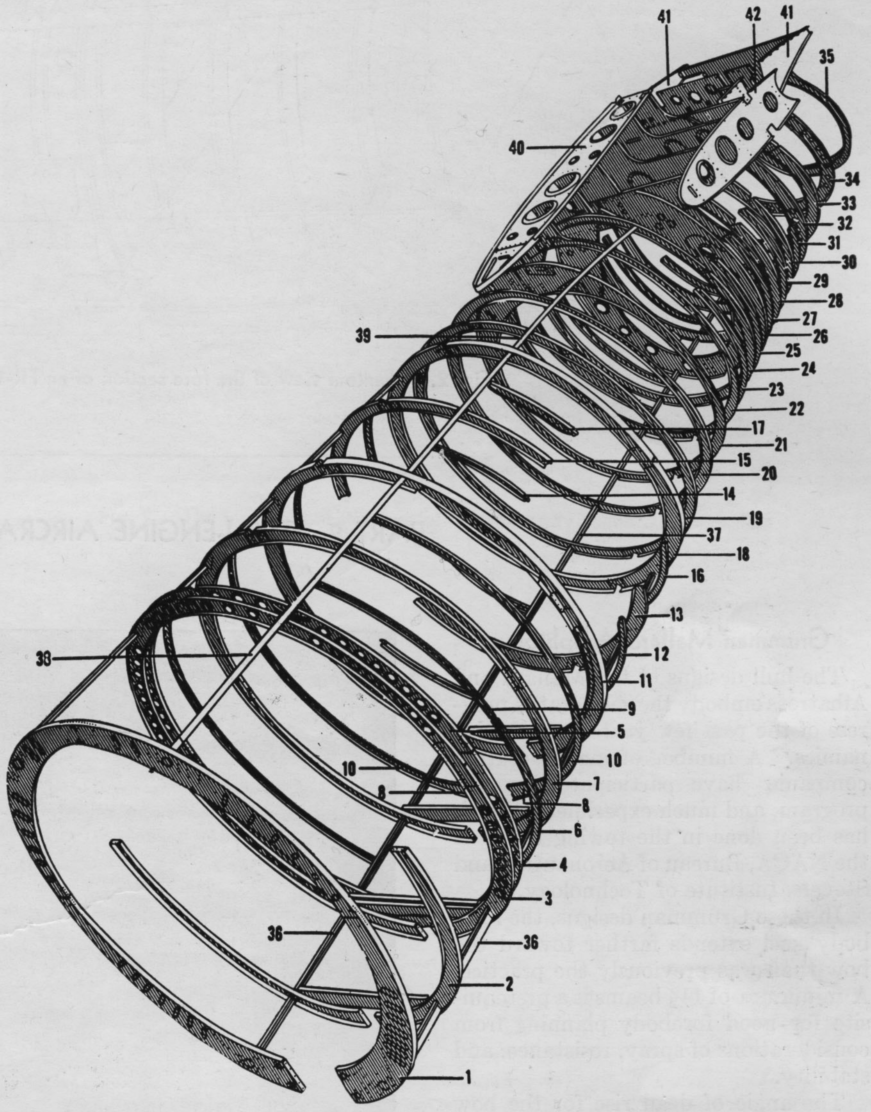


Fig. 1. The aft fuselage of the FR-1 is a circular monocoque structure with empennage surfaces so mounted that there is no interference with the exhaust from GE I-16 turbojet engine which is mounted in the front part in which horizontal cross members can be seen between stringers.

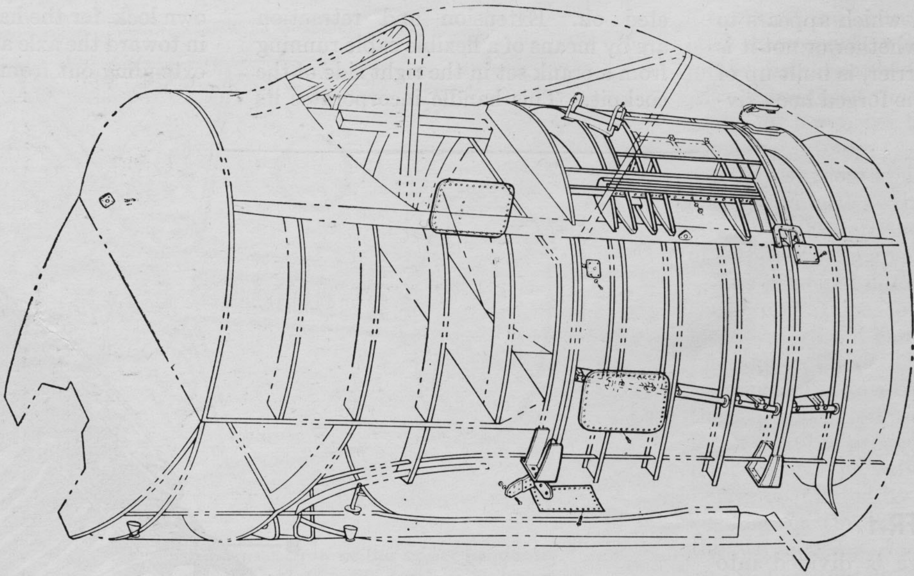


Fig. 2. Phantom view of the fore section of an FR-1 fuselage.

PART 2. TWIN-ENGINE AIRCRAFT

Grumman Mallard Amphibian

The hull designs of the Mallard and Albatross embody the accelerated progress of the past few years in hydrodynamics. A number of manufacturing companies have participated in this program, and much experimental work has been done in the towing tanks of the NACA, Bureau of Aeronautics, and Stevens Institute of Technology.

In these Grumman designs, the forebody keel extends farther toward the bow than was previously the practice. A minimum of 1½ beams is a prerequisite for good forebody planning from considerations of spray, resistance, and stability.

The angle of dead rise for the bow sections is quite large, resulting in a very sharp entry in waves and therefore a reduction in impact. The chine flare is generous at the bow and extends all the way aft to the step.

Structurally, the bottom of the forebody hull consists of closely spaced stringers and widely spaced frames (1). Skin gauge is 0.051 in.

A reasonably deep ventilated step characterizes the afterbody. Geometrically, the step depth is 8 per cent of the beam at the keel, but ventilation increases the effective depth consider-

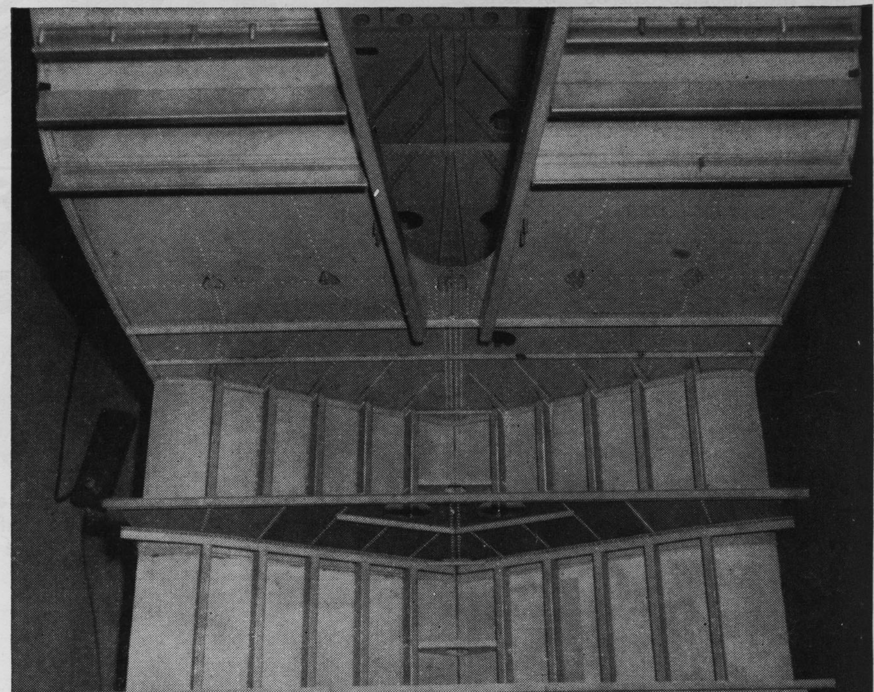


Fig. 1. Structure of the hull bottom at the forebody.

ably. Until a few years ago conventional step depths were approximately 5 per cent of the beam, but it was found that 7 to 12 per cent was necessary to prevent bad skipping characteristics. If, however, a 5 per cent step was ventilated by approximately 2 per cent b^2 ventilation, its performance reached that of the 7 to 12 per cent class.

A warped afterbody is used in which the angle of dead rise at the step is increased toward the tail and then decreased at the rear step to the previous degree of dead rise. This feature improves landing stability.

There are also vertical side steps or breaker steps just forward of the tail cone and rear step to improve directional stability at low speeds. The Mallard was one of the first aircraft in which steps of this type were incorporated in the original hull lines.

Structurally the afterbody bottom uses no through stringers but has closely spaced frames (2). Skin thickness is 0.040 in.

Watertight compartmentation is shown in (3). When bow compartment 1 is flooded, the water line is at *B*. The water line is at *C* when the largest aft compartment, No. 3, is flooded. The extremely long cabin required two compartments, 2 and 3, and this necessitated a watertight seal at the flood line. Since control leads, electrical wiring, and hydraulic lines run upward on the bulkhead behind the pilots, the only complication was the cabin heater duct which is below the floor level. Intercompartment flooding is prevented by two cork float-actuated flapper valves which prevent flow through the duct as the water rises.

The wing tip float (4) has high dead rise at the bow to create a sharp entry and reduce drag loads as the float plunges in and out of the waves at taxiing speeds. It is also characterized by a faired step for the reduction of water resistance and air resistance, and an airfoil contour deck for the development of additional hydrodynamic lift when running fully submerged. A design check on the feasibility of retraction indicated that the moderate increase in speed and range was more than offset by a decrease in pay load and an increase in cost.

The floats are easily removable and have two watertight compartments. The aftercompartment may be made available as an auxiliary fuel tank providing a capacity of 50 gal in each float and increasing the cruising range to approximately 1,700 miles.

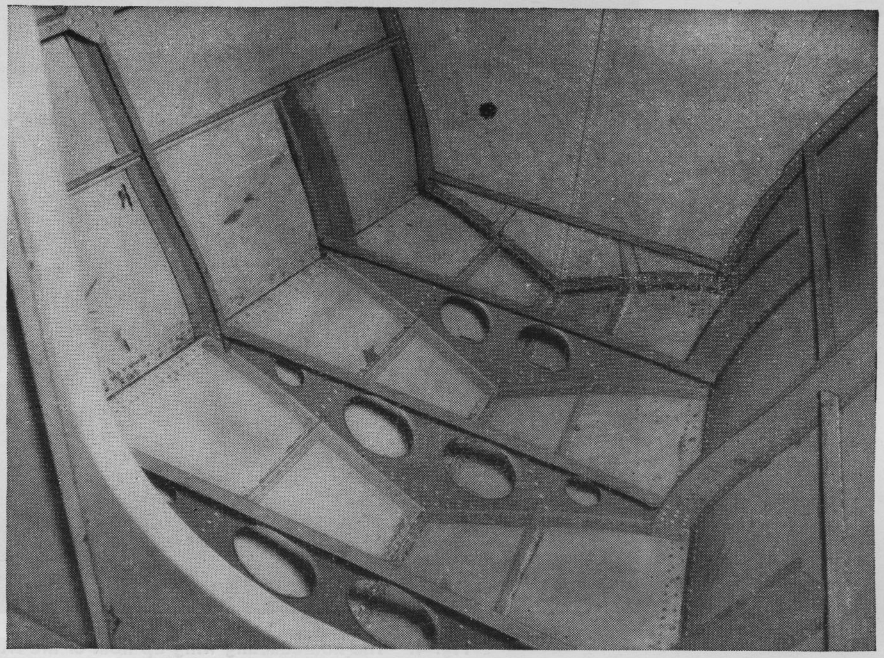


Fig. 2. The hull bottom structure of the afterbody, stations 428 to 495

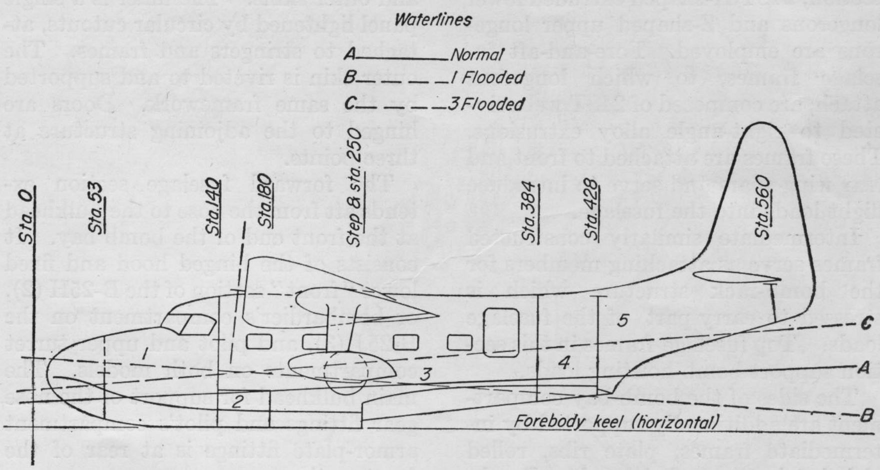


Fig. 3. Watertight compartmentation diagram, showing water lines.

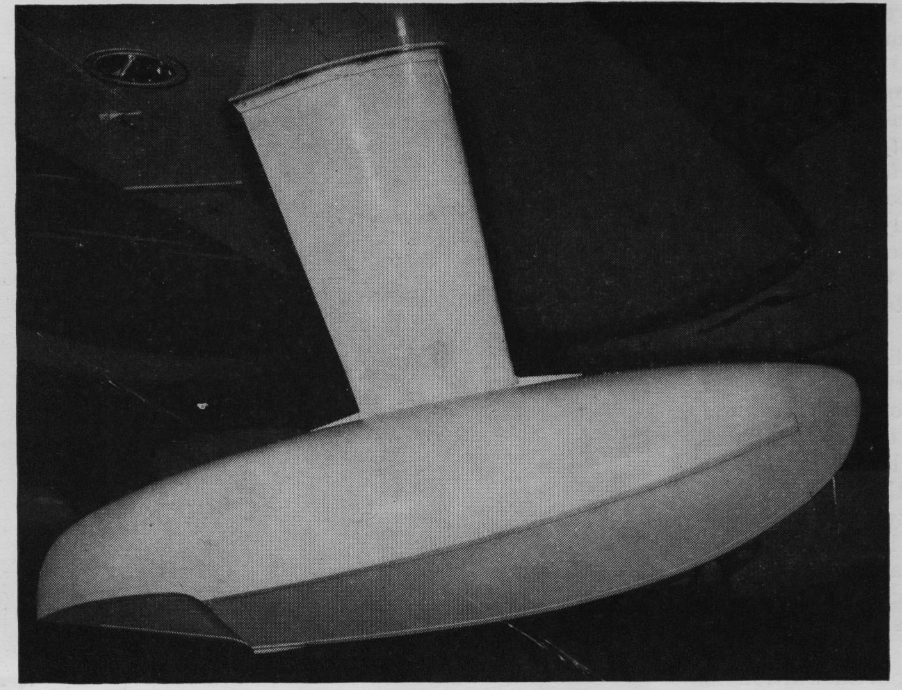


Fig. 4. The nonretracting wing tip float of the Mallard.

North American B-25

The bomb-bay section (1) of the B-25, built integrally with the wing center section, is the backbone of the bomber. To resist a major portion of fuselage bending loads carried by this section, 24ST H-shaped extruded lower longerons and Z-shaped upper longerons are employed. Fore-and-aft fuselage frames, to which longerons attach, are composed of 24ST webs riveted to right-angle alloy extrusions. These frames are attached to front and rear wing spars and serve to introduce flight loads into the fuselage.

Intermediate similarly constructed frames serve as attaching members for the bomb-rack structure which is stressed to carry part of the fuselage loads. Top fuselage frames in this section support bomb-hoisting loads.

The sides of the bomb-bay compartment are additionally supported by intermediate frames, plate ribs, rolled alclad stringers, and channels. Bomb-rack rails which support bomb loads are bolted to the rack attachment frames. The compartment roof also serves as the floor of a crawlway permitting fore-and-aft travel by the crew during flight. This floor is of .032-in. 24ST alclad stiffened by hat-shaped rolled angles and extrusions. Transverse shear loads are borne by the floor along with the top fuselage skin. At this section, the fuselage is skinned with lap-jointed 24ST alclad varying from .032 on top to .051 on the sides.

Doors of the bomb bay have inner and outer skins. The inner is a single panel lightened by circular cutouts, attached to stringers and frames. The outer skin is riveted to and supported by the same framework. Doors are hinged to the adjoining structure at three points.

The forward fuselage section extends aft from the nose to the bulkhead at the front end of the bomb bay. It consists of the hinged hood and fixed lower "front" section of the B-25H (2), or bombardier's compartment on the B-25J (3), and pilot and upper turret compartments on both models. The main bulkhead for support of the nose gear fittings and pilot's compartment armor-plate fittings is at rear of the front section.

The cockpit enclosure is made of Lucite or Plexiglas and glass sheet, set in metal frames and sliding panels. The floor section is an integral structural feature of the fuselage. On the B-25H, the 75-mm cannon is in the crawlway used by the bombardier in the B-25J. Housing for cannon is on the left side, under the cockpit floor of the pilot's compartment, and serves structurally, as a torque box.

The cannoneer's compartment on the B-25H is known as the upper turret compartment on the B-25J and is behind the pilot's enclosure. It includes the front entrance hatch, upper turret guns, and, on the B-25H, is used as the loading station for the cannon.

Four longerons are the largest single load-carrying fuselage members, and bear axial tension and compression forces due to the action of bending. The shape and size of each depends on the load carried, and except for the extruded longerons in the bomb-bay assembly, they consist of channels formed from 24SO alclad sheet later heat-treated to 24ST.

Extending the full fuselage length are two lower longerons. They are continuous within individual fuselage sections, later bolted together to form a running fuselage structure. In the fixed portion of the front forward section, the left longeron (on B-25H and J) is a Z-shaped member formed of .051 alclad (later heat-treated). Because of higher load factors, the thickness of the corresponding right lower longeron is increased to .091.

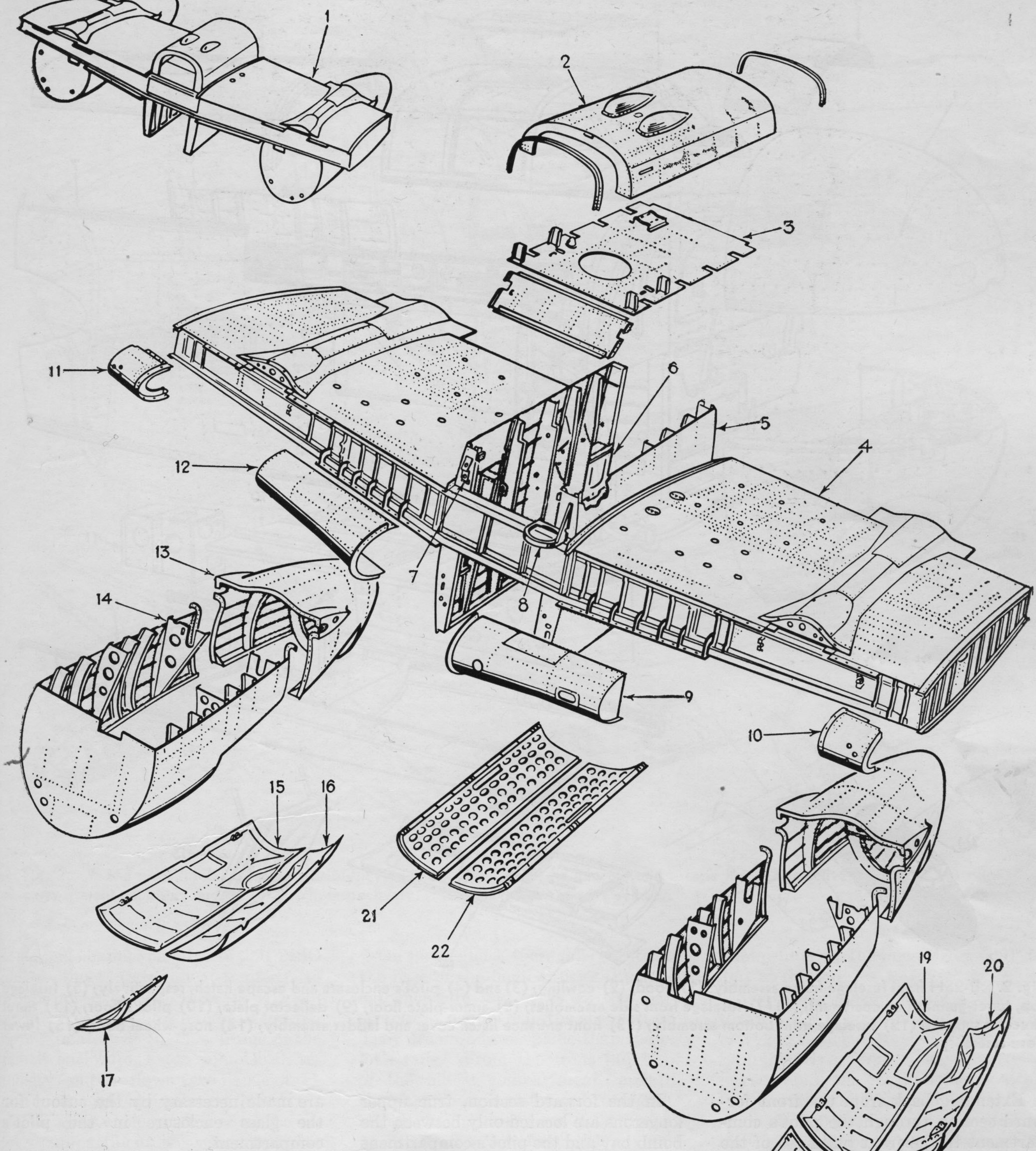


Fig. 1. Fuselage intermediate frame assembly: (1) composite structure; (2) top frame; (3) crawlway floor assembly; (4) center section covered assembly; (5) bomb-bay fuselage side assembly; (6) bomb sling door; (7) fuel cross-feed bracket; (8) hydraulic reservoir support; (9) to (12) wing nose assemblies; (13) nacelle, aft; (14) nacelle, forward; (15) to (20) main landing gear doors, (21) (22) bomb-bay doors.

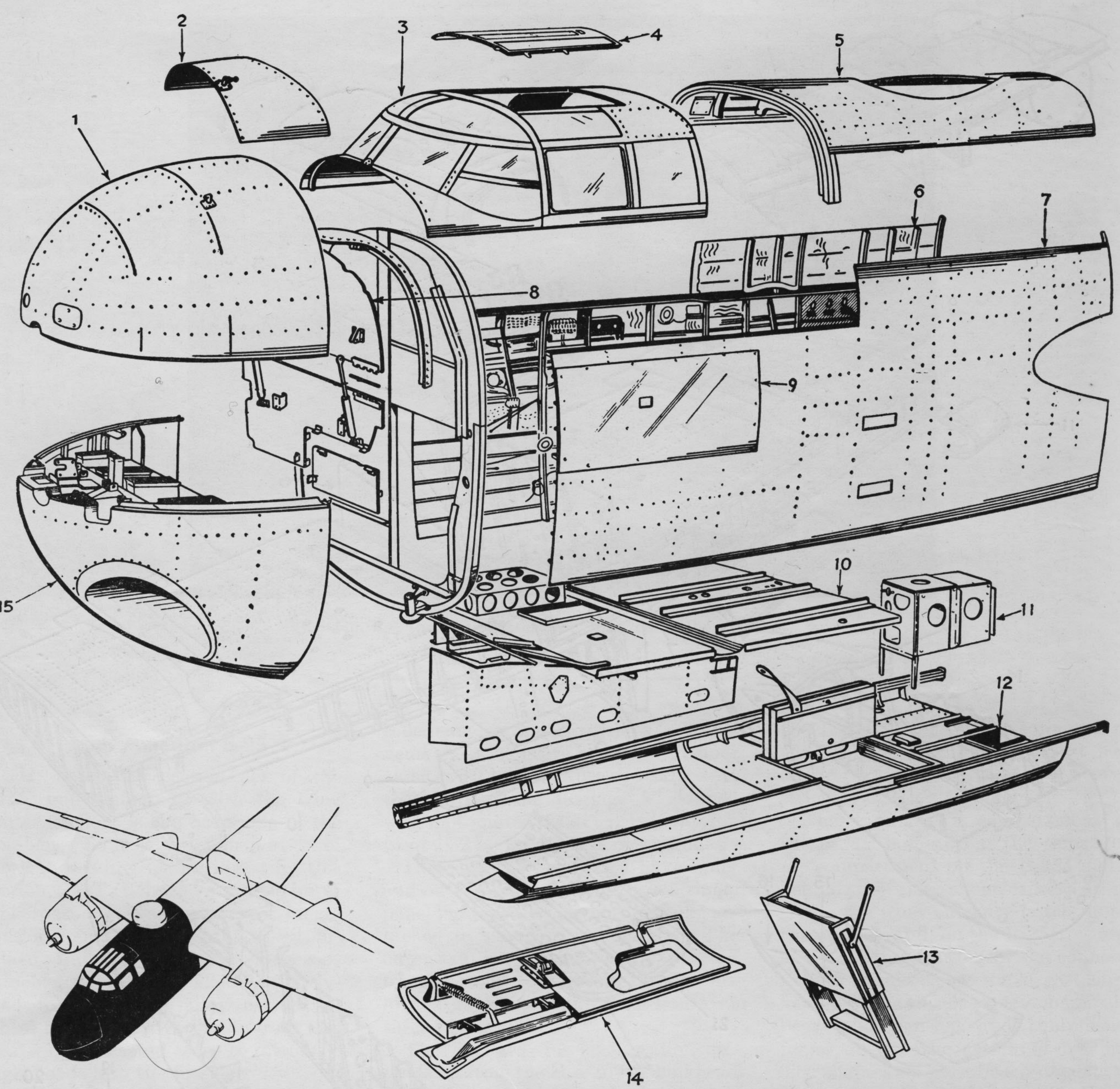


Fig. 2. B-25H front fuselage frame assembly: (1) hood; (2) cowling; (3) and (4) pilot's enclosure and escape hatch, respectively; (5) fuselage top, turret-gunner's compartment; (6) (7) fuselage front side assemblies; (8) armor-plate floor; (9) deflector plate; (10) pilot's floor; (11) turret structure support; (12) fuselage front bottom assembly; (13) front entrance hatch cover and ladder assembly; (14) nose-wheel door; (15) lower nose assembly.

Extending back from the front forward section through the pilot's compartment to the front bulkhead of the bomb-bay section, lower longerons are downward-flanged .064 24ST alclad channel members, reinforced along the skin side flange by an extruded angle. Approximately in the middle of the pilot's compartment, an .081 rear section is spliced in with an .064 doubler of the same material.

In the forward section, true upper longerons are located only between the bomb bay and the pilot's compartment rear bulkhead, and are .091 24SO formed channels heat-treated to 24ST. They are otherwise replaced by members known as bombardier's rails and pilot's rails, and serve as upper extensions of the longerons. "Breaking" of the upper longerons and continuation of the structural frame on a lower plane are made necessary by the cutout for the glass enclosure in the pilot's compartment.

Each pilot's rail runs longitudinally along the fuselage side, just below pilot's side window. Rails are attached to the fuselage finishing angle at the end of the gun-turret compartment, extend forward, and are connected to the front bulkhead of pilot's compartment. Each is a downward-flanged

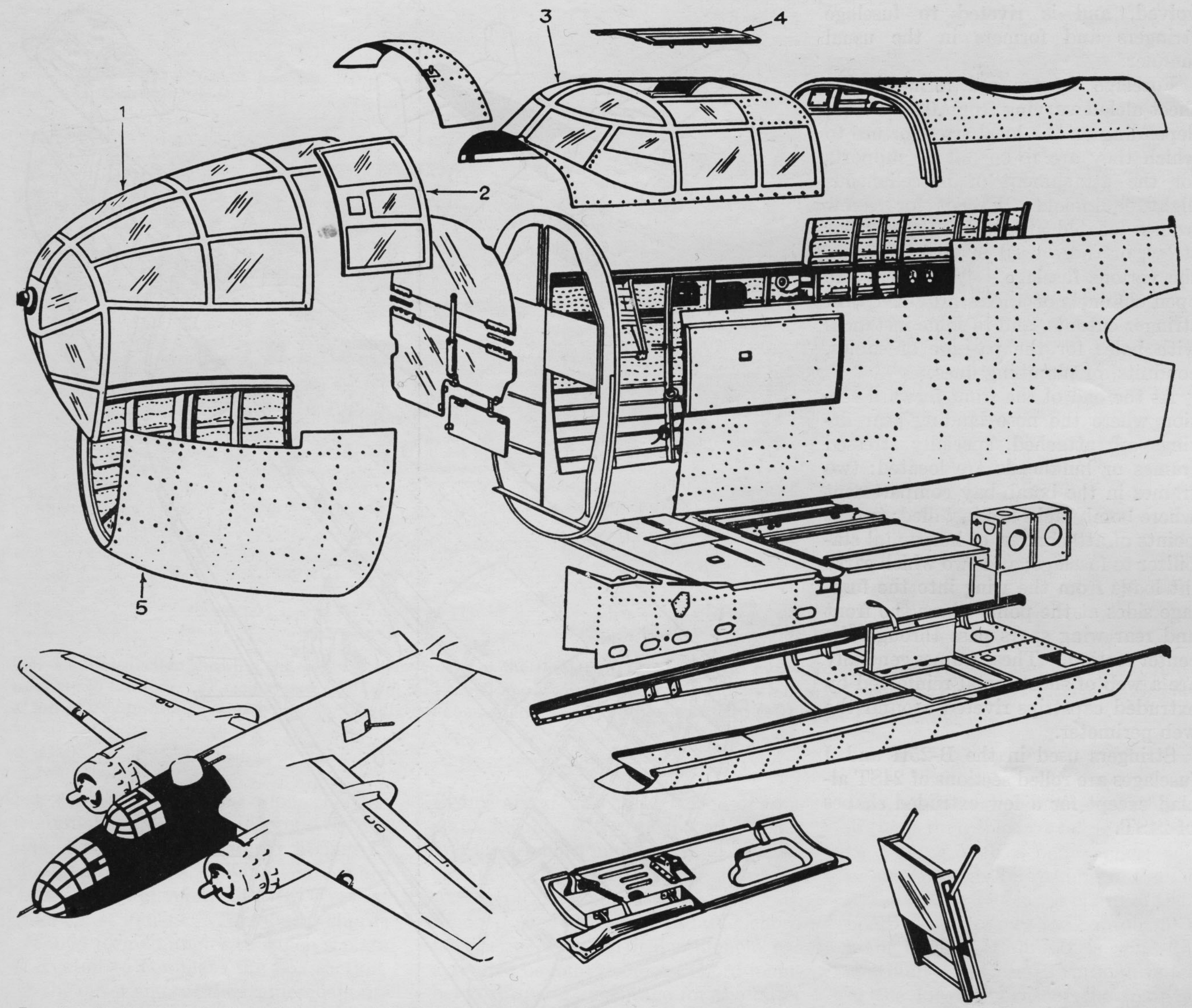


Fig. 3. B-25J front fuselage frame assembly: (1) and (2) bombardier's enclosure and escape hatch, respectively; (3) and (4) pilot's-compartment enclosure and escape hatch, respectively; (5) fuselage front lower assembly.

L-shaped channel member of .091 24SO alclad sheet (later heat-treated) to which an extruded angle is riveted. Forward and aft of a bulkhead located approximately at the first frame of the pilot's enclosure, loads diminish in intensity, and the downward flange of the extruded angle is machine-tapered.

The glass enclosure frame of the pilot's compartment is secured by wing channel nuts riveted to the inner flange of the pilot's rail.

The bombardier's rails, which extend on each side of the fuselage in line with the first pilot's enclosure frame to the front of the forward front nose section on the B-25H, provide a second forward extension of upper longerons.

On the model J, these rails constitute the base of the bombardier's transparent enclosure and serve as the main structural members of the nose section. They are on a lower plane than the pilot's rails. From the front bulkhead of the pilot's compartment forward, they are downward-flanged .050 24SO alclad channel members (heat-treated to 24ST after forming) and are .064 thick, rearward. Except for armor plate, the fuselage is skinned with 24ST alclad ranging from .051 to .025.

The rear fuselage section (4) includes the portion aft of the bomb-bay compartment. The upper longerons are flanged channel of formed and subsequently heat-treated 24SO alclad sheet, diminishing in thickness from .091 to .051 at the tail.

The lower longerons are broken at the waist-gun position and consist of .081 24ST alclad riveted together to form an H section. They are reinforced along the inside flanges of the two U sections. An additional doubler angle of .091 24ST alclad is riveted to the bottom inboard side of the lower U section for a distance of 12 in. immediately aft of the bomb-bay rear bulkhead. The lower longerons aft of the waist-gun positions are channels formed of sheet alclad of diminishing thickness.

Skin is 24ST varying from .064 to .032, depending on the stresses in-

volved, and is riveted to fuselage stringers and formers in the usual manner.

Fuselage frames are formed from sheet alclad varying from .032 to .064, depending on the local stress or use to which they are to be put as supports for the attachment of miscellaneous flight equipment. Except for a few frames located at points of particular stress, or those used in attachment of the various fuselage sections, they are open channels or angles provided with stringer cutouts, and in some instances with holes for the passage of cables, conduits, or plumbing lines.

At the end of the front forward section where the nose landing gear fittings are attached, specially stressed frames or bulkheads are located: two frames in the bomb-bay compartment where bomb racks are installed; two at points of attachment of horizontal stabilizer to fuselage; and two which carry lift loads from the wing into the fuselage sides at the point where the front and rear wing spars pass through the center section. These frames generally are a web of sheet metal reinforced by extruded capstrips riveted around the web perimeter.

Stringers used in the B-25H and J fuselages are rolled sections of 24ST alclad except for a few extruded shapes of 24ST.

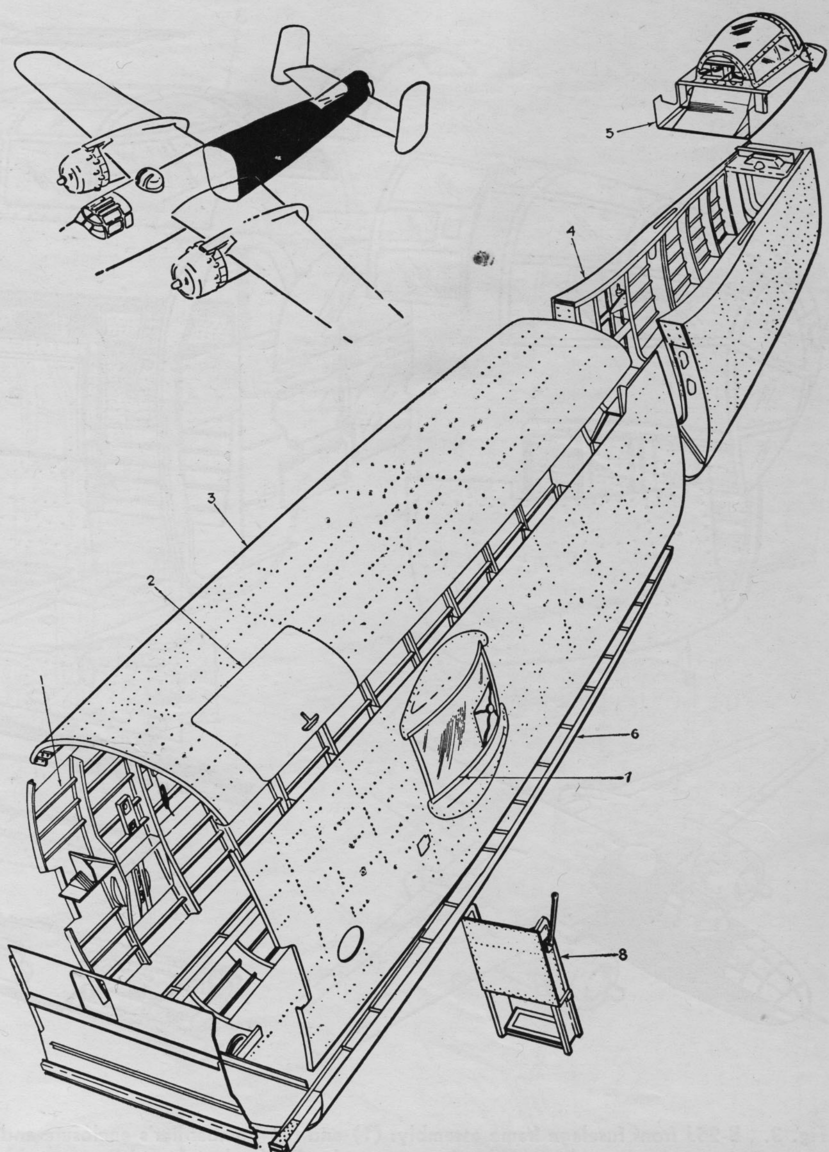


Fig. 4. Fuselage rear frame assembly: (1) side frame assembly; (2) life-raft door; (3) top assembly; (4) and (5) tail gunner's compartment and canopy, respectively; (6) bottom assembly; (7) waist-gun window; (8) rear exit hatch.

Fairchild C-82 Packet

Of semimonocoque construction, the Packet fuselage (1)—54 ft long, approximately 10 ft wide, and 13 ft high—consists, generally, of main and auxiliary frames, stringers, beams, and skin. To facilitate construction, the fuselage has been resolved into six major sections: main body, sides, upper front, upper rear, nose compartment, and rear cargo-door compartment.

The main body section (2), foundation of the fuselage, supports the cargo floor. Composed of frames, stringers, and longitudinal and transverse floor beams (3), the cargo floor is approximately 40 ft long from the point of nose attachment to the cargo-door hinge point. From floor bottom to bottom contour it varies in thickness from 9 in. at its ends to 20 in. at the center. The main frames, except for main spar frames, are spaced approximately 35 in. apart. The main spar frames are so designated because they fall directly below the wing center section spars and are spaced 72 in. apart.

The main frames of the main body section (4, 5) are U-shaped web beams with straight upper chord members and vertical chord stiffeners. The lower chord members are hydro-pressed contoured C sections. Web gauges vary from .025 to .040, the latter being at the main spar frames. The upper chord members vary from .032 to .064, and stiffeners are rolled-angle sections with gauge varying in accordance with the thickness of the web.

The main frame at the end of the main body section has a double-web or

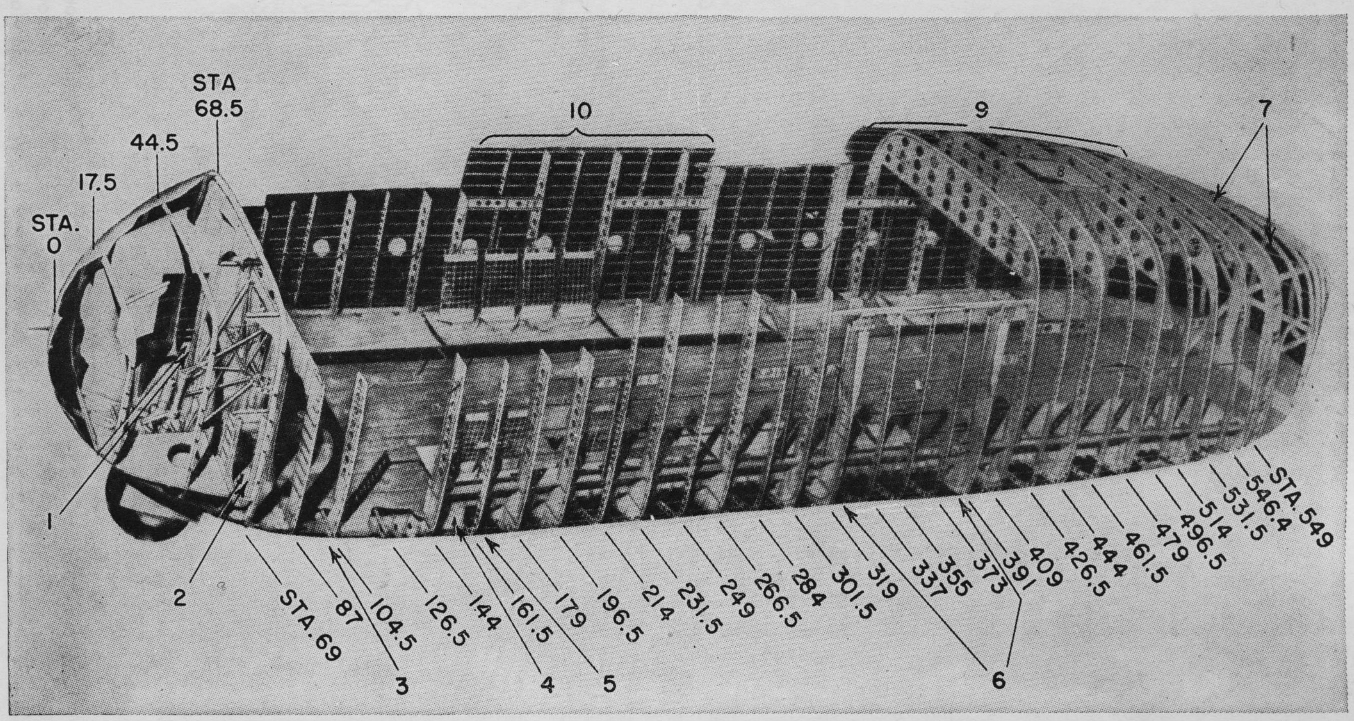


Fig. 1. Perspective showing the general arrangement of the fuselage: (1) opening to hydraulic equipment compartment in nose section; (2) opening to lavatory; (3) main frame; (4) main body section outboard beam; (5) auxiliary frame; (6) main spar frame with fuselage-to-wing fitting at top of box portion; (7) cargo doors; (8) life-raft compartment; (9) upper rear section; (10) upper front section.

box construction. The upper chord is trough-shaped, .072 thick, and is designed to receive the upper fittings of the loading ramps. Web members are .032 and are reinforced by vertical channel stiffeners. The lower chords are .064 formed angles to which a plate is riveted to complete the box section. At the outer ends of the frame, just outboard of the outboard longitudinal beams, cast fittings are provided to receive spring-loaded jack points to afford support for the aft end of the fuselage while it is being loaded.

Auxiliary frames are constant-depth C sections varying from .025 to .032, with heavier gauge between the spar frames, and are located between the main frames to reduce the length of the skin panels to approximately 17 in.

There are seven longitudinal floor beams in the main body section: two outboard, two inboard, two intermediate, and one at the center. Outboard beams, 96 in. apart, are located above the floor, the beam on the right side running the full cargo-compartment length, and that on the left extending from the rear cargo-door frame to the front entrance door, from where it runs forward below the floor. Beams are of web construction of constant height, with rolled-angle upper and lower chord members, and tapered channel-section vertical web stiffeners. At a typical section, the beams are 15 in. deep with .020 webs and .051 chord members. The vertical stiffeners are extended beyond the lower chord member to provide anchorage for the outer ends of the transverse floor beams. The lower chord rests on and is riveted to the main frame upper chord members, and the web of the outer beam is riveted to the vertical stiffener which forms the inboard edge of the U-shaped main frame. The web of each beam has cutouts for attachment of eight ventilators. At the ventilator cutouts, the web is increased to .040, and an additional drop-hammered section is used to stiffen the beam.

Fabricated in lengths to fit between main frames, the inboard beams are located below the floor and spaced approximately 54 in. apart. They have web construction with rolled-angle upper and lower chord members and vertical web stiffeners. A typical section has .040 web, .060 upper caps, and .040 lower caps. The webs are riveted to the vertical web stiffeners of the main frames. Chord members on either side of the main frames are made continuous by joining with a splice plate which passes through an opening in the main frame web. The lower chord of the inboard beam follows the contour of the main body section. It is spliced for continuity and passes through notches in the lower chords of the main and auxiliary frames.

Intermediate beams, also located below the floor, are made up in sections to fit between main frames and are spaced 30 in. apart. They are web beams, with upper and lower chord members spliced for continuity, and have vertical web stiffeners. The beams have a constant depth of 10 in. and do not extend to the contour. A typical section has a .032 web and .051 upper and lower caps.

Similar in construction to the intermediate beam but having two webs spaced by channel stiffeners instead of a single web, the center beam is designed to take loads imposed by the spare engine hold-down fittings used for bolting the power plants mounted on cradles, or to receive eyebolts for lashing other heavy cargo. Hold-down fittings are cast, have a center

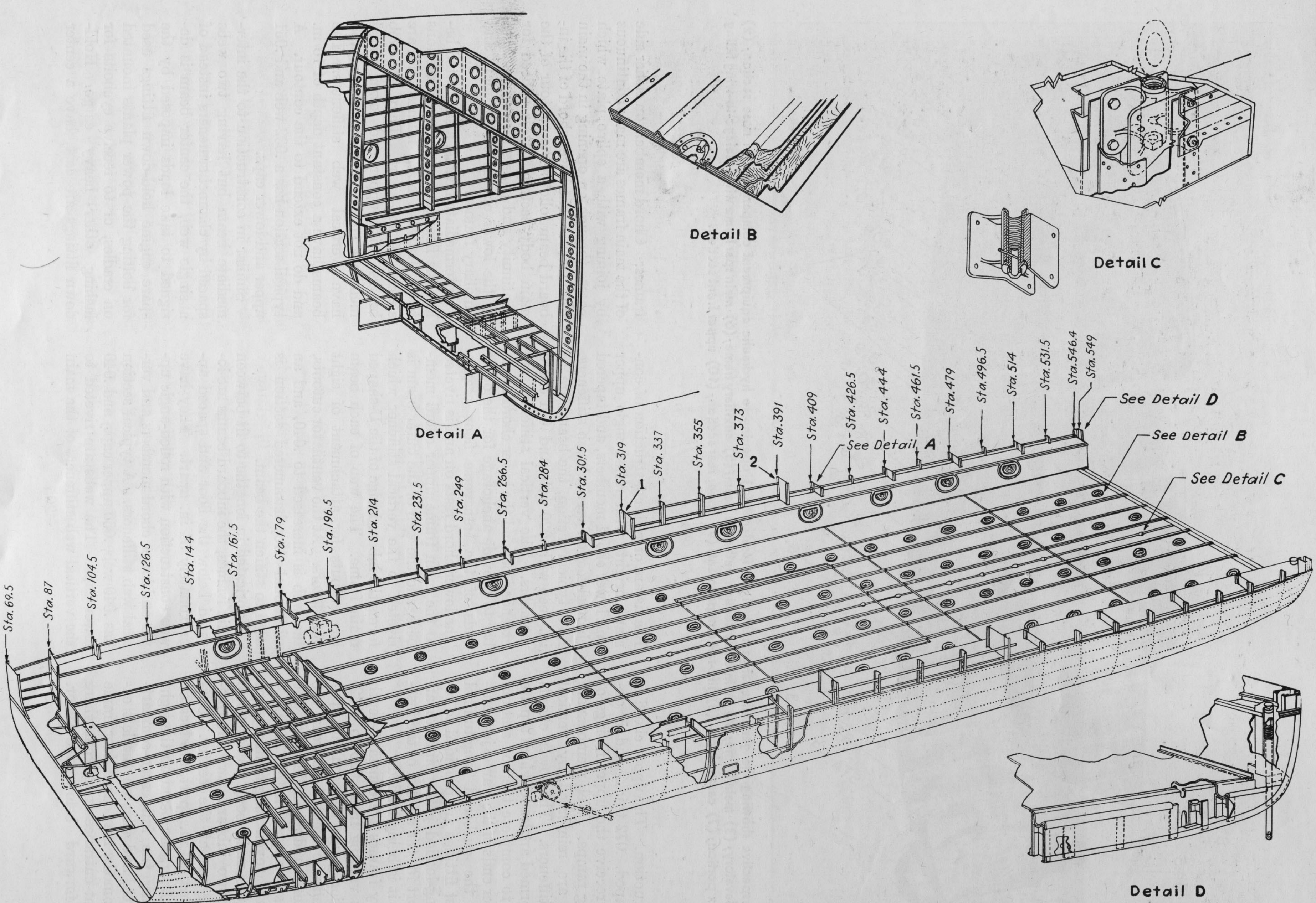


Fig. 2. Main body section of the fuselage. Main spar frames are seen at (1) and (2) with aerial delivery door between them in the cargo floor. The detail views are: (*a*) typical floor section; (*b*) portion of metal-covered plywood floor showing cargo tie-down fitting and corrugations backed with maple filler strip; (*c*) center beam engine tie-down fitting shown with removable eyebolt (dotted) and also in cross section; (*d*) double-web and main frame having trough-shaped upper chord to receive the loading ramp fitting. At the outer end is seen a spring-loaded jack point for support of the fuselage aft end during loading.

Fig. 3. View of the main body section looking aft, showing longitudinal beams and frames: (1) outboard beam; (2) inboard beam; (3) intermediate beam; (4) center beam; (5) main frame; (6) web stiffener; (7) channels for tying in transverse hat sections; (8) aerial delivery container opening with the center beam removed.

boss and two flanges, and are designed to sustain a load of 5,000 lb in any direction. The boss is drilled to receive a steel bushing tapered for a $\frac{3}{4}$-in. bolt, and the flanges provide means of attaching the fitting to the center beam web.

Between the main spar frames, the center beam is removable and is equipped with fittings at the upper and lower chord members to engage mating fittings on the spar frames. The beam is secured by four bolts, and when it is removed, the inboard beams and main spar frames form a box opening approximately 52 in. wide by 72 in. long for dropping aerial delivery containers (6).

The transverse floor beams are hat sections, generally of .032 gauge, and are spaced 5.8 in. on centers. Used in sections of the cargo floor usually heavily loaded, they extend from the outboard beams to the intermediate beams and are supported in their length by the inboard beams.

Designed for heavy loading and to withstand abrasion and impact, the cargo floor is constructed of three-ply Douglas fir plywood core to which is bonded a thin sheet of aluminum alloy on the bottom side, and a heavier sheet on top having corrugations spaced 10 in. on centers. The corrugations are backed with maple strips to prevent crushing of the metal and prolong the life of the floor by facilitating the sliding of cargo. Between corrugations, the floor is coated with nonskid paint.

To facilitate fabrication and maintenance, the floor is built in removable sections. Over the aerial delivery opening in the fuselage center, the floor consists of two doors, hinged at outer fore-and-aft edges to the inboard beams, designed to withstand the same degree of loading as the floor proper.

A pattern of hold-down fittings is spaced on 20-in. centers in the floor. Each is provided with a ring and stud for lashing the cargo, and designed to sustain an upward load of 1,250 lb and a side load of 500 lb.

The fuselage sides, consisting of main and auxiliary side frames, longitudinal stringers, and skin, are constructed as separate units for ease of fabrication.

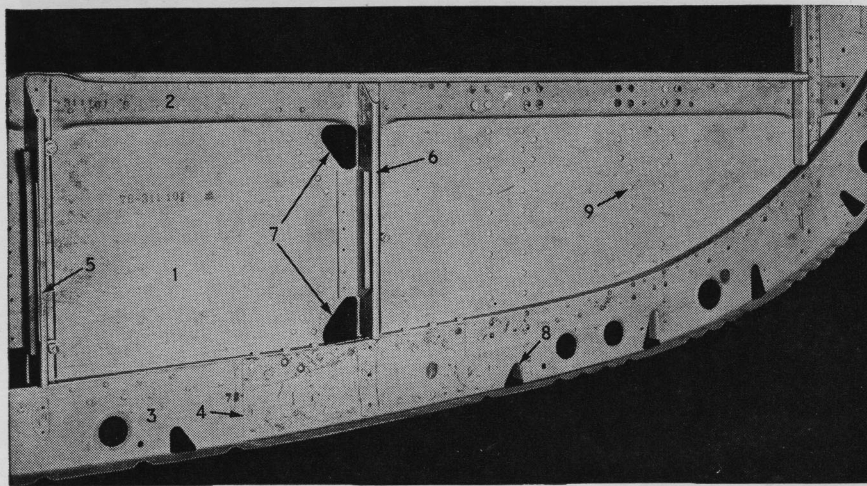


Fig. 4. Portion of the main body section main frame: (1) web; (2) upper cap; (3) lower cap; (4) splice plate; (5) and (6) angles for web attachment of intermediate beam and inboard beam, respectively; (7) upper and lower cutouts for inboard beam caps; (8) stringer cutout; (9) attachment of hat-section stiffener on reverse side of the web.

The main side frames have flanged holes and beaded webs, rolled lip angles placed back to back to form the inboard chord members, and C-section outboard chord members formed to the fuselage contour.

Side spar frames provide the tension tie to the wing center section spars and are tapered from a single frame at the lower portion to a box frame at the upper portion to afford a base for the fuselage-to-wing attachment fittings. One of these fittings is mounted on the inboard flanges of the frame, and the other to the outboard flanges. Cast spacer blocks are provided between the webs to stabilize the upper end and form a rigid base for attachment of the fuselage-to-wing fittings.

All frames, except the spar frames, are notched to permit installation of continuous rolled bulb-angle stringers.

Twelve 9-in. holes provided in the skin for the flush mounting of circular windows are reinforced by an angle on the inside.

The fuselage upper front section is between the end of the cockpit floor, at station 196½, and the wing center section front spar, at station 319 (1). It consists of a series of arched frames to which horizontal beams are riveted.

The arched frames are pressed C sections with return lips on the inside flange and flanged holes in the webs. At a typical section, the main frames are 4½ in. deep, auxiliary frames are 3¼ in. deep, and the frame gauge is .032. The horizontal floor beams are built-up I members having .020 web and a depth of 5 in. at a typical section. Fore-and-aft intercostal beams are C sections with return lips on both upper and lower flanges and flanged holes in the web. The gauge is .032 and depth is 5 in. at a typical section. Arched frames are notched for installation of continuous bulb-angle fore-and-aft stringers.

A cutout for an airscoop in the top of the upper front section supplies fresh air to a secondary heat exchanger and ducts mounted just below the fuselage contour. The accessory floor of the upper front section is used for mounting radio and navigational equipment. The transverse floor beam, at the end of the cockpit floor, where the accessory floor commences, is 27 in. deep. The upper chord and vertical stiffeners of this member support the accessory floor, and the lower chord members sustain the cockpit floor and its longitudinal beams.

Behind the transverse floor beam are formers with sides tying into the vertical stiffeners and tops secured to the accessory floor longitudinal beams. Formers are rounded at the bottom and notched to permit passing of stringers. A metal cover is riveted to the formers and stringers to box the full width of the fuselage. The box beam thus formed serves to stiffen the crossbeam of the frame at the forward end of the accessory floor (station 196½). On the crossbeam are mounted control pulley brackets and engine-control bell cranks.

The upper rear section extends from the rear center section spar (station 391) to the end of the fuselage at the cargo door hinge point. Of monocoque construction, it embodies main and auxiliary frames, bulb-angle longitudinal stringers, and skin.

Because of equipment mounted in this section, the main frames are designed as deep-web beams, measuring 31 in. at a typical section. The .020 webs have flanged lightening holes. The lower chord members are double-

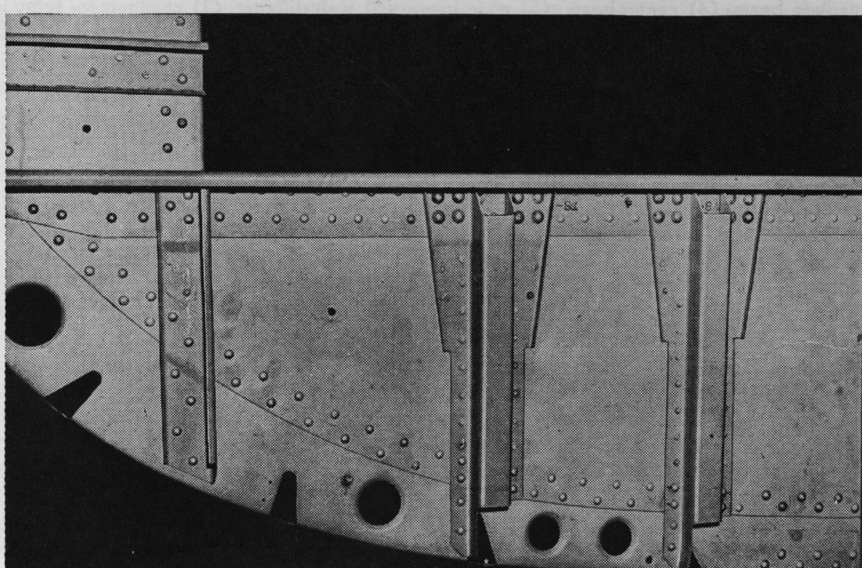


Fig. 5. Corner of the main frame. Hat-section stiffeners are shown at the center.

rolled lip angles riveted on both sides of the web, and the upper chords are pressed C sections or angles conforming to the fuselage contour.

Between station 391 (wing rear spar) and station 409 (first main frame) is a box structure housing and supporting three automatic pilot servo units for operating ailerons, elevator, and rudders. Provision also is made for supporting pulley brackets for the servo emergency disconnect mechanism. On both sides of the servo units, fittings are installed on the rear spar and on the first main frame for supporting two tubes for mounting the aileron, elevator, and rudder control sectors.

On the center line, between station 409 (first main frame) and station 444 (second main frame), a structure is provided for mounting the flap-operating mechanism.

Between station 444 and station 479 (third main frame), another box structure houses the self-ejection life raft (7), and the door of the raft installation also affords an emergency exit for personnel. The box walls and vertical stiffeners also provide support for mounting eight G-1 oxygen bottles and associated tubing.

The space between the upper front and upper rear fuselage sections is taken up by the wing center section. On the upper surface of the wing is built the continuation of the fuselage—fuselage cap—similar in construction to the fuselage proper and serving as a tie between the wing, upper front section, and upper rear section.

The main body section, left and right sides, and the upper front and upper rear sections are riveted together to form the center fuselage section.

Bulkhead beams, supporting between them a horizontal upper beam and two vertical side beams, are at the forward end of the fuselage at stations 69½ and 87. On these beams are mounted support brackets for hinging the nose landing gear structural members and retracting mechanism.

Station 69½ (forward bulkhead) is a .020 web with vertical and horizontal stiffeners and flanged contour members around the outer portion. In the center of the bulkhead is an opening to provide clearance for the nose wheel and gear structure, and on each side of this opening is another passage for access to the nose compartment. At the top of the bulkhead, on each side of the center opening, is a cutout covered by a pyramidal housing to provide

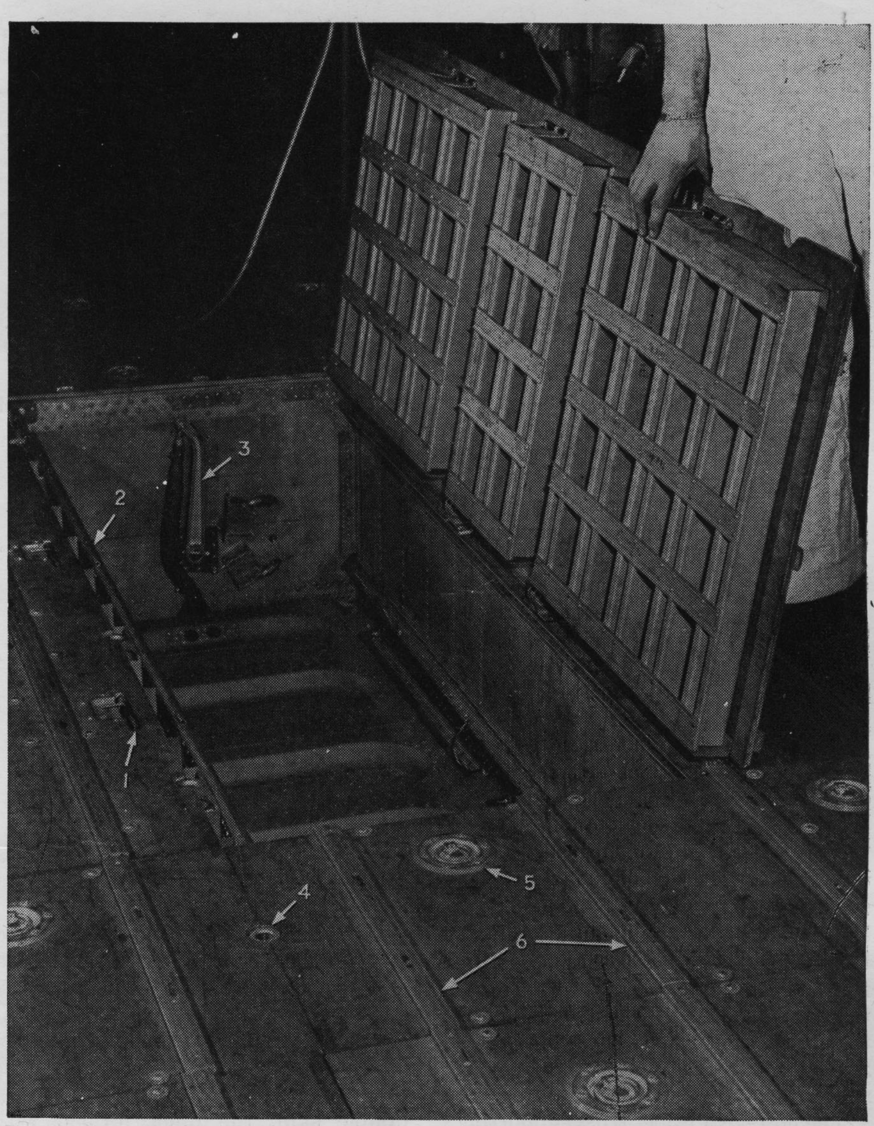


Fig. 6. Seen in an open position is half of the floor installation above the aerial delivery doors. Tracks drop down from the ceiling, fit into spaces on each side of the middle under floor section, and guide containers through doors. Also shown are: (1) latch for floor over doors; (2) center beam, removable for aerial delivery; (3) motor-driven actuator for doors; (4) engine hold-down fitting in center beam; (5) cargo tie-down fitting. Raised strips (6) are being replaced by corrugation.

clearance for the pilot's and the copilot's control columns in the extreme forward position.

Station 87 (aft bulkhead), a combination unit at the lower portion and having a former frame attached at the top, is also provided with openings on each side. Clearance for the nose gear retraction mechanism is provided by three smaller openings covered on the aft face by an enclosure consisting of vertical formers, stringers, and skin fitted with an access door to permit inspection (from cargo compartment) of the nose gear units.

The horizontal and vertical beams between bulkheads at stations 69½ and 87 are of conventional web, chord, and web stiffener construction. The horizontal beam has an .020 web and is 35 in. wide. The web of the vertical beam is .064 above the nose beam, is .064 above the nose-gear torque shaft fittings, and is .040 below. Secured between the bulkhead frames, the horizontal beam and vertical beams form a rigid structure to absorb the loads imposed by the nose gear and transfer them to the forward end of the fuselage.

On the inboard sides of the vertical

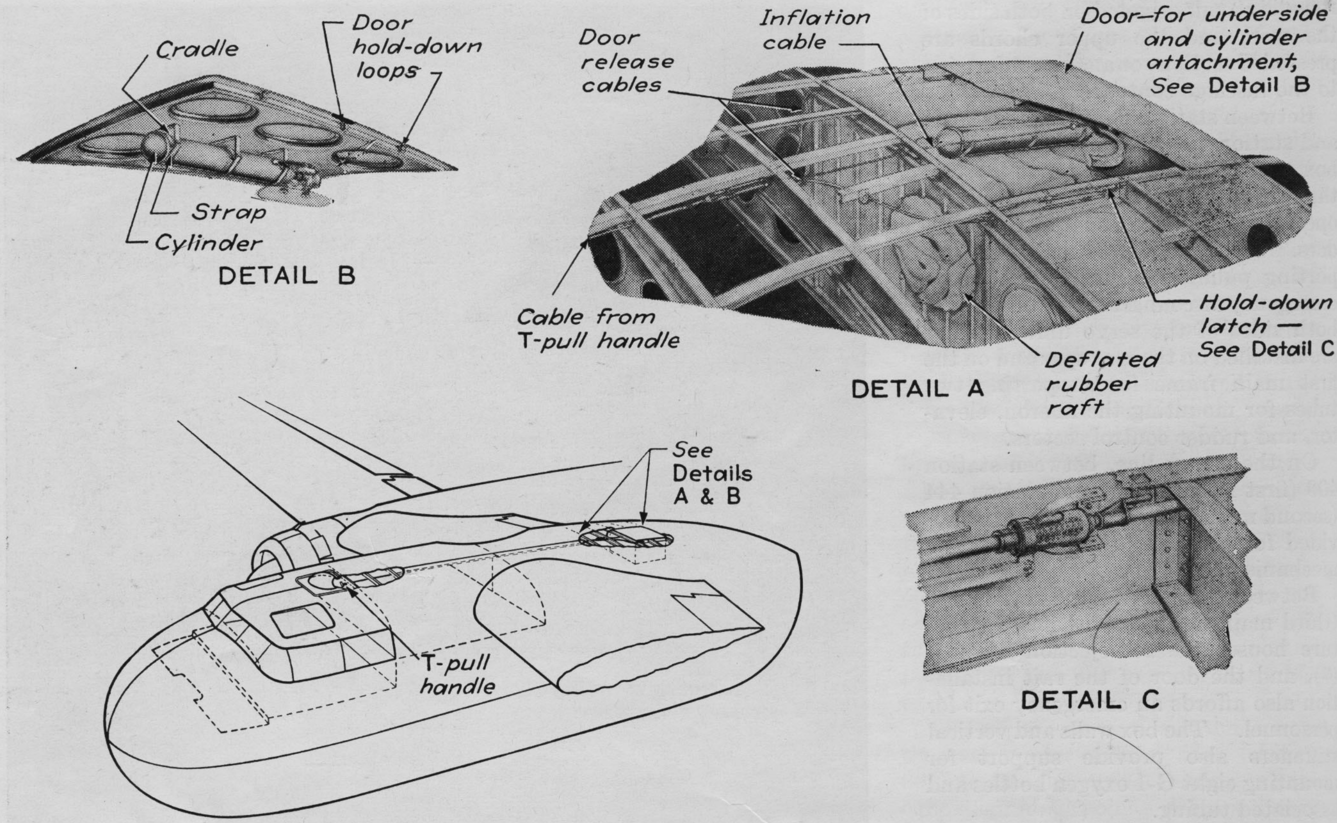


Fig. 7. Life-raft installation. Shock cords under the collapsed raft eject the latter when the hold-down latch is released.

beams, fittings are mounted to support the nose-gear lower truss and retraction shaft. The outboard sides of the vertical beams are reinforced in the region of the fittings by two horizontal beams about 10 in. deep which run between the bulkhead frames.

The nose-gear upper truss supporting fittings are bolted to an auxiliary box beam formed by adding the bulkheads and the front and bottom sides at the junction of the horizontal beam and the aft bulkhead frame at station 87. The box beam also contains the support fitting for the upper terminal of the nose-gear gravity-drop energy-absorber unit.

One of the three major airplane jack points is mounted at the lower portion of the aft bulkhead, bolted to a vertical channel stiffener.

The nose section extends forward from the bulkhead frame at station 69 and is a conventional semimonocoque structure having pressed C-section frames, stringers, and skin. It is divided into three compartments by two vertical bulkheads which run full height from the frame at station 69 to that at station 17.5.

The nose gear is housed, in retracted position, in the center compartment, and at the bottom are three doors operated by the gear. The two rear doors are hinged at the outer edges and the front door is hinged at the forward edge. All are constructed of double skin, the inner formed with depressions.

The left compartment is the lavatory equipped with chemical closet, tissue holder, relief tube, water tank, basin, etc. A circular window affords lighting and visibility (8).

Hydraulic equipment is housed in the right compartment, and a quick-removable panel in the vertical bulkhead provides ready access for inspection and servicing of the nose gear. Entrance to left and right compartments is through openings in the bulkhead at station 69.

The rear portion of the fuselage is constructed in the form of two large clamshell-type doors which swing on a vertical hinge line at fuselage sides and, when fully opened, provide a loading area 8 ft square (9).

The doors consist of C-shaped frames, stringers, skin, and a vertical frame where the C frames terminate. They are held in a closed position by latches located in the center and rear members of the vertical frame.

Movement of one door with respect to the other is eliminated by the use of four shear pins. Two pins are at the bottom of the first C frame and engage two sockets in the fuselage rear frame. The other two are in the rear of the right-hand door and engage sockets in the left-hand door.

In each door two floor sections are provided: a rear floor for rear observation and a forward floor for paratrooper jumping station. In the side of each cargo door is a smaller door for paratrooper egress. It is of double sheet construction with the inner skin recessed in sections to stiffen the outer skin. Hinged at the rear edge, it opens inward and has provision for locking in the closed position and hooking in the open position.

The cockpit enclosure (10, 11), consisting of formers, stringers, and skin, incorporates a windshield, side windows, and top escape hatches.

The sloping V-shaped windshield is divided into four sections because

of the length of the enclosure span. The outer panels in front of the pilot and copilot are nonshatterable double-plate glass with space between for passage of heated air for anti-icing. The center windshields are single nonshatterable plate glass. All panels are flush-mounted on the outside.

From the outboard side of each outer windshield panel, a curved Plexiglas transition section extends to the forward side window and contains a clear-vision panel approximately 6 in. square, hinged at the rear edge and opening inward to provide unobstructed vision in event of failure to keep the windshield free of ice.

The forward side windows of nonshatterable plate glass slide aft, and behind each is a fixed Plexiglas section for general convenience of the crew.

Escape hatches, fitted with doors which can be jettisoned from the crew compartment, are above the pilot's and copilot's seats. Each hatch door consists of a metal frame, Plexiglas panel, quick-release mechanism, and guide wires for sliding a sunshade.

An astrodome is mounted on a square metal frame door above the navigator's station, releasable from the inside and outside to provide an escape hatch for the navigator and radio operator.

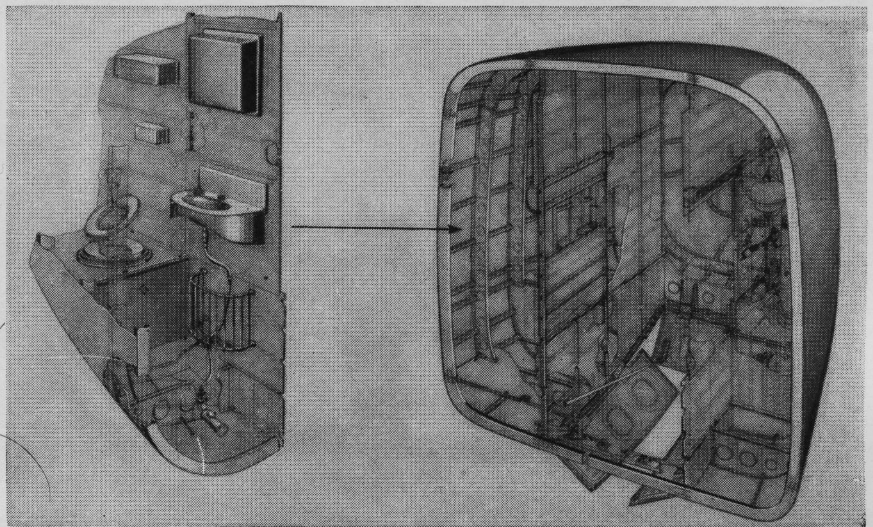


Fig. 8. Nose section compartments. Hydraulic equipment is at the right, nose gear doors in the center, and lavatory at the left.

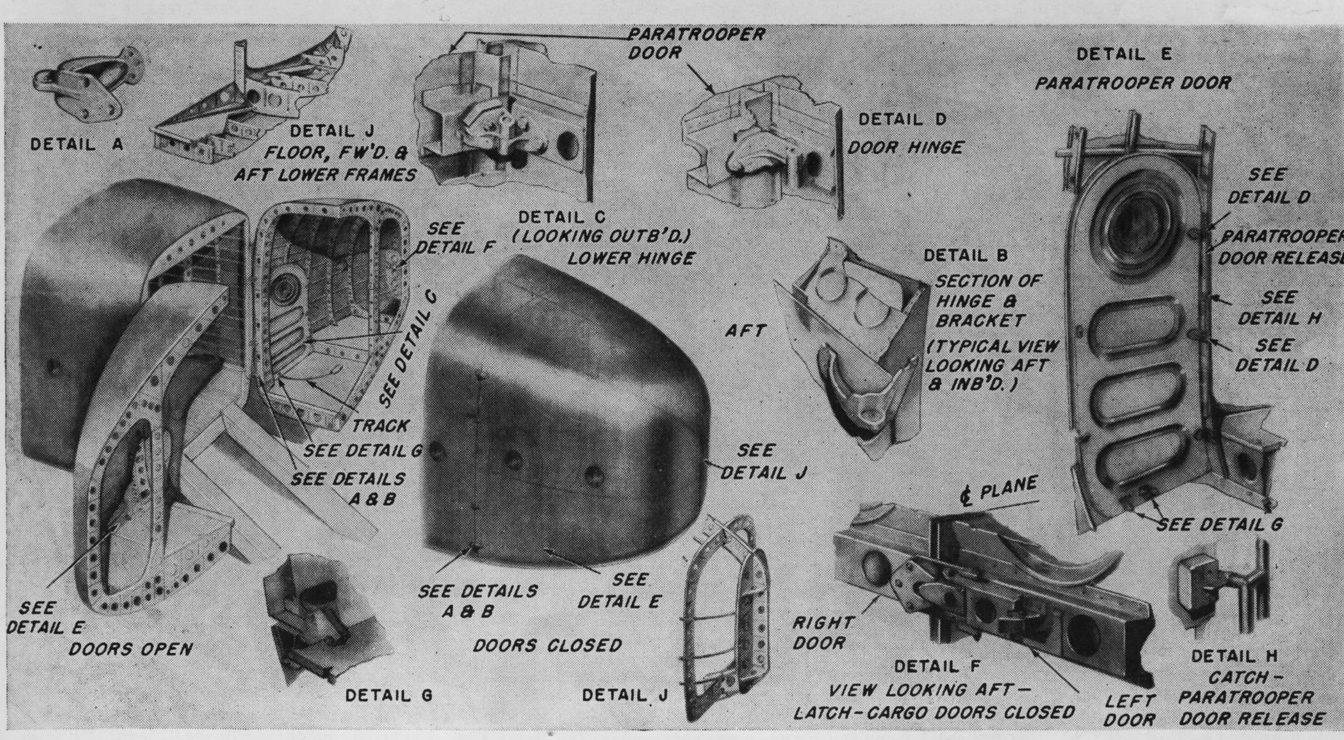


Fig. 9. Details of the rear cargo-door installation.

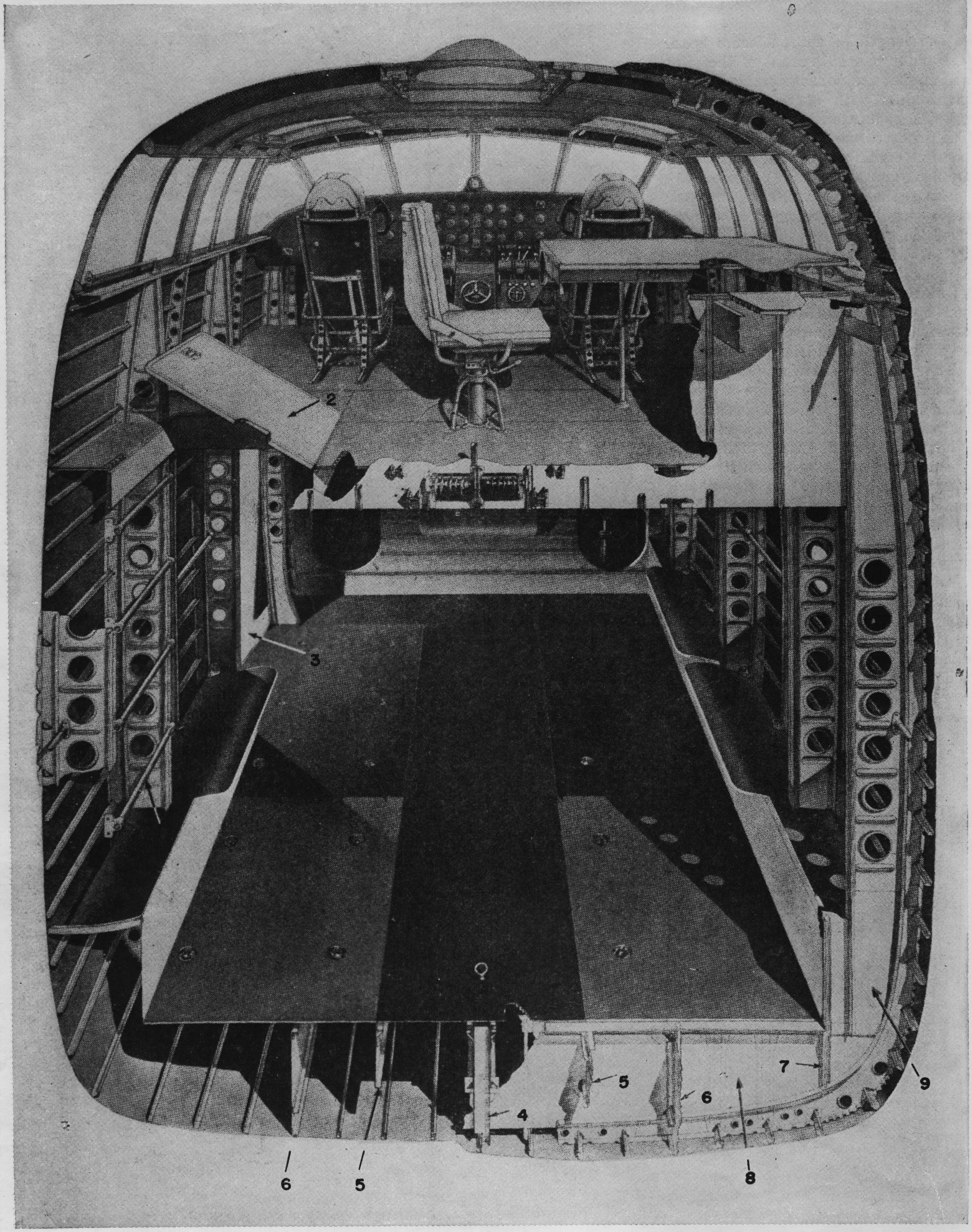


Fig. 10. View showing the fuselage and cockpit interiors. The radio operator's seat, omitted to clarify details, is located behind the pilot's and the navigator's positions. Fuselage side seats are being replaced by canvas seats supported by a swivel leg attaching to a floor tie-down fitting. Other details are: (1) ladder to cockpit; (2) cargo compartment-to-cockpit door; (3) front cargo door; (4) center beam; (5) intermediate beam; (6) inboard beam; (7) outboard beam; (8) main body section main frame; (9) main side frame.

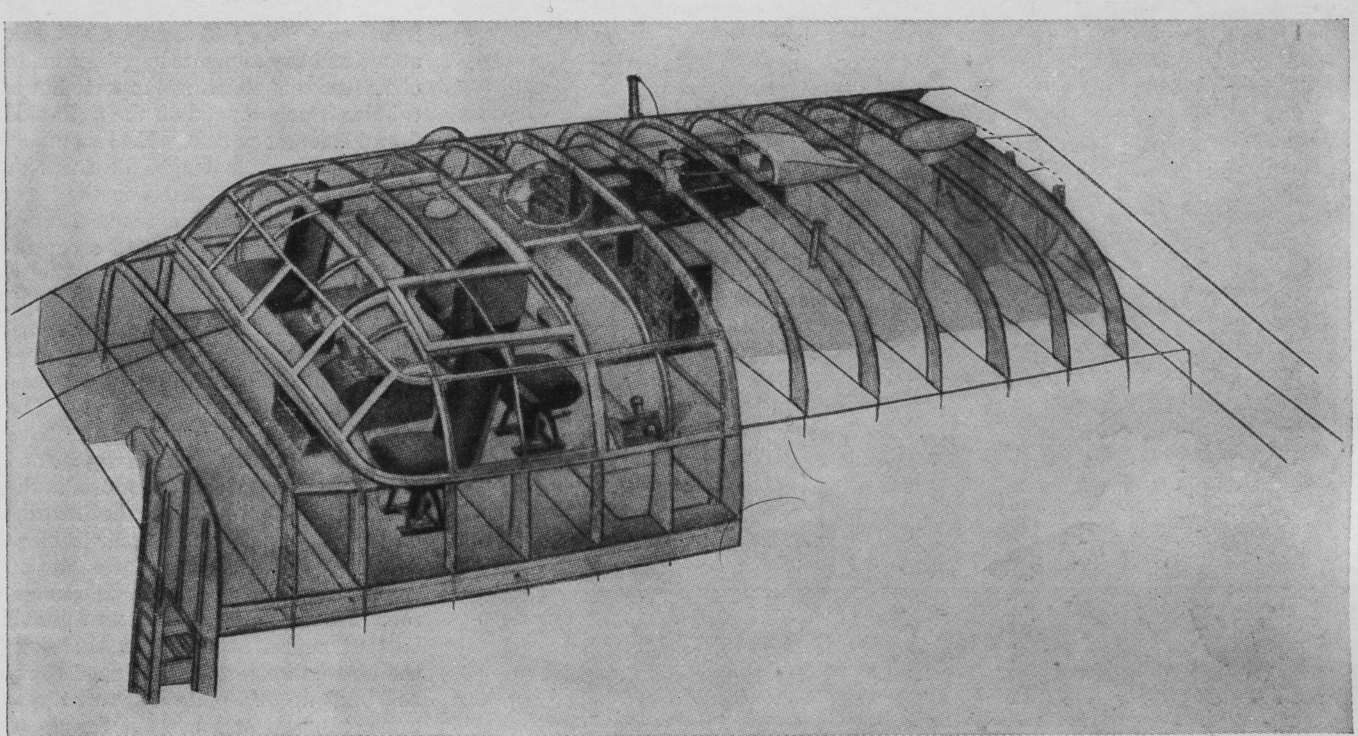


Fig. 11. The view of the cockpit enclosure at the top left shows the seating arrangements for pilot, copilot, navigator and radio operator; the accessory floor for radio equipment is shown at the rear.

Bristol Beaufighter

Divided into three sections of all-metal monocoque construction, the fuselage of the Beaufighter is composed of front and rear fuselages and a rear frame. The construction is of alclad formers, mainly of lipped Z section, extruded light-alloy beaded angle stringers, and alclad skin plating. The formers and stringers are secured to the skin by countersunk aluminum alloy rivets but are not attached to each other, the formers being notched to clear the stringers.

The front fuselage structure (1) is mainly of alclad Z section and channel-section formers and skin plating, with extruded beaded angle fore-and-aft stringers. Substantial keel members extend forward, and two longerons are fitted left and right. The top longeron and a longitudinal member on each side carry a shelf for the engine auxiliary controls and other equipment. The bottom longeron is near the floor level. The pilot's seat is supported by a tubular structure, mainly of mild steel. Below the windscreen and reaching forward, are nonmagnetic bulletproof armor plates. The nose piece forward of this is detachable. Blast tubes for

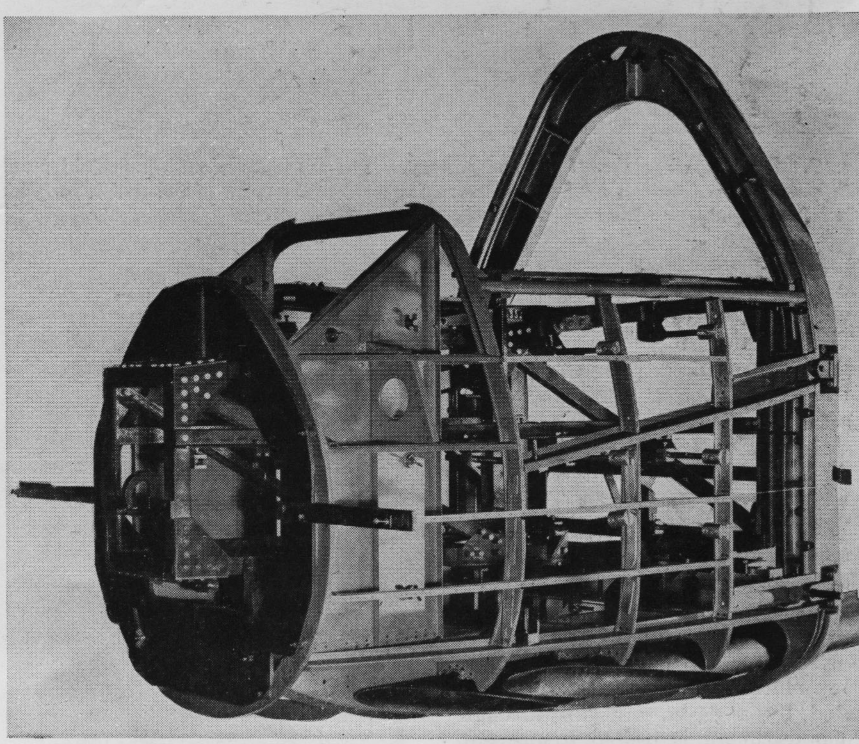


Fig. 1. The nose frame is built between the heavy back forging and front member of sheet metal. U-section stringers connect extruded T-section ribs. At the bottom, on each side, are blast tubes for machine guns.

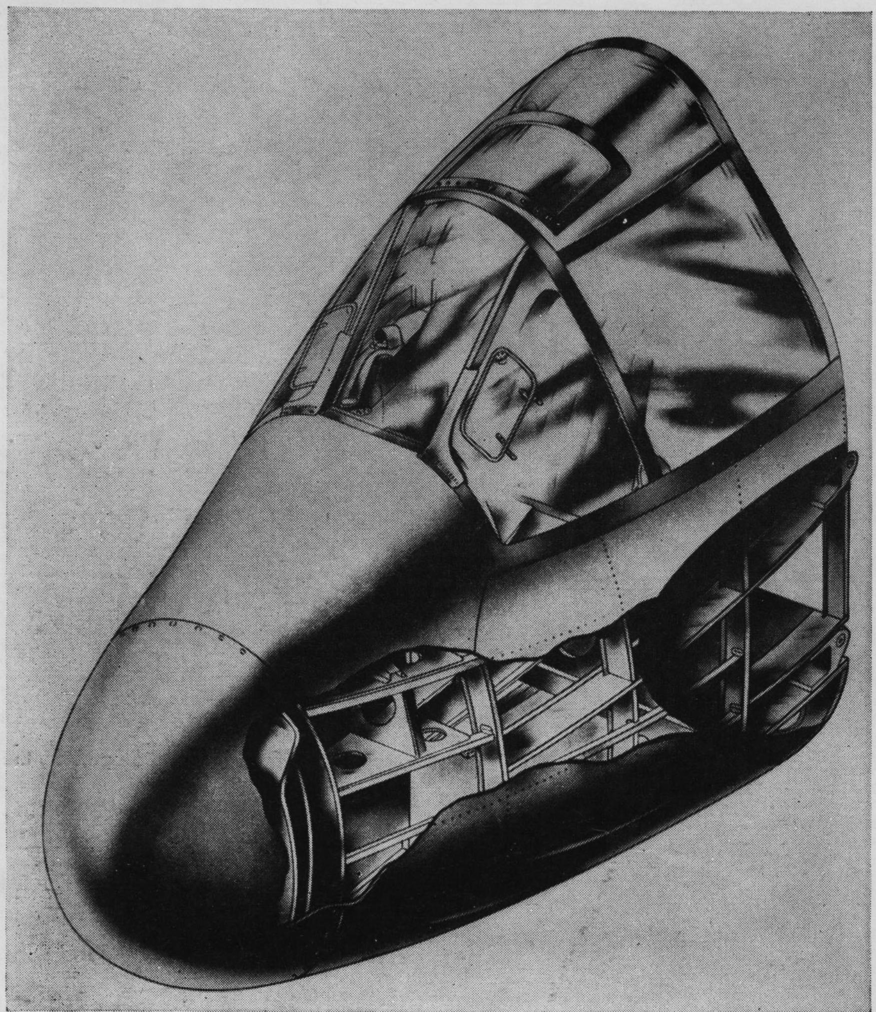


Fig. 2. Front fuselage showing armor protection and the bulletproof wind-shield fitted with direct-vision windows for bad weather. The emergency hatch in the roof is for pilot exit in crash landings The seat is collapsible for emergency exit.

the four guns are under the floor outside the keel members. The front hatch is between the main wing spars.

The roof and part of the sides of the cockpit are covered with transparent sheeting, and a bulletproof windscreen (2) is fitted at the front. The framework of light-alloy tubular members and magnesium-alloy castings is bolted to the main structure. Transparent sheeting, mounted on rubber, is secured to the framework by light-alloy cover strips. Two screens compose the pilot's windshield, the outer of ¼-in. Triplex, and the inner one of six ¼-in. glass plates, making a bulletproof shield. The screens are separated by a ⅜-in. air gap through which warm air is passed to prevent frosting.

The rear fuselage (3) is generally similar to the main structure of the front section. The observer's hood, about midway along its length, is made of transparent sheeting supported on a tubular frame, hinged on the right side for an emergency exit. Keel members extend the whole length of the rear fuselage. Armor is fitted on the front of the rear spar and extends upward 20 in., while two doors with a central handle are above the spar.

There are several double formers of lipped channel in the rear fuselage placed back to back some distance apart with a plate riveted across their flanges on the inboard side. The formers at the center wing spars have Hinduminium forked blocks riveted and bolted to the web of the channels at the bottom for attachment to the box ribs on the center wing. The rear fuselage is strengthened by three longerons on each side. The top and middle longerons are of channel riveted to top and bottom angles attached to the skin; the bottom longeron is of lipped channel, built up of a plate and two Z sections, the top and bottom flanges of which are attached to the skin.

The rear frame is comprised of lipped Z-section formers, bulb-angle stringers, and alclad skin plating. The aft end of the frame is formed by a sternpost carrying the rudder bottom hinge extended upward to carry the top hinge. A special section stringer is near the bottom on each side. Housing for the tail-wheel unit when retracted is provided by an aperture in the underside of the frame, boxed in with aluminum-manganese alloy and plastic sheet.

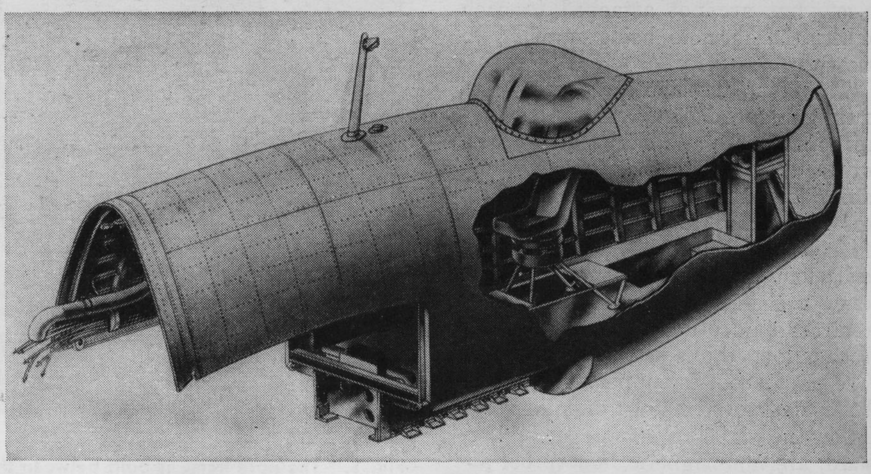


Fig. 3. A section of the fuselage at the turret showing the reversible gunner's seat, astro hatch, and aileron standard.

The ends of the skin plating of the front and rear fuselage sections butt together, secured by setscrews and Simmonds nuts to butt straps underneath. Other attachments are made at the Hinduminium blocks on the center-wing box ribs. Two blocks, near the bottom of the front fuselage, are riveted to channels which in turn are riveted to angles on the skin and secured by high-tensile steel bolts in steel bushings to the formed horizontal pair of blocks at the bottom of the center-wing box ribs. The curve of the fuselage over the top of the wing is strengthened by extruded plate angles. Rear horizontal blocks on the box ribs are attached by bolts and steel bushings to a block riveted to each middle longeron of the rear fuselage.

The front entry and exit hatch, under the fuselage between the front and rear spars, is a door with a double skin of alclad on alclad formers. The door is pivoted midway along its length on a tubular shaft supported on two bearings attached to the keel members. The door has a short ladder at the bottom and a step with a spring-loaded flap for entry. Catches, holding the door in open or closed position, are operated by three handles, one under the front fuselage and two inside the plane. The rear hatch is generally similar.

Curtiss C-46 Commando

A major point in the preliminary design study, cabin pressurization for substratospheric operations, resulted in the Curtiss Commando's "double-bubble" fuselage design.

In cross section, the fuselage, except for the extreme aft portion, is formed by two intersecting circles with the common chord of intersection at the cabin floor line (1). By using two circles, the frontal area was reduced without losing the ideal pressure section, and the common chord line serves the dual purpose of tying the circles together and providing the floor structure.

The main cargo compartment (2) affords some 2,300 cu ft of space, having a length of 48 ft and maximum width and height of 9 ft 10 in. and 6 ft 8 in., respectively.

As a general cargo carrier, the standard floor design permits a concentrated load on any one transverse beam of approximately 435 lb (3). For uniform loadings, wall to wall, the standard floor will accommodate approximately 70 lb per sq ft; for uniform loading over the middle half of the floor, 100 lb per sq ft can be safely loaded.

Cargo tie-down fittings (4) are set at the juncture of the fuselage wall and the floor about 21 in. apart for the full length on both sides. Similar fittings are set in the walls 31 in. above the floor line directly above those at the floor line, and a third group is set in the roof, 25 in. on either side of the center line.

None of the fittings project into the cabin, thus eliminating the danger of chaffing or puncturing fragile packages close to the wall. Protection from damage by cargo to the fuselage bulkheads and skin is given by rows of metal tubes running the full compartment length up to a height of 31 in. above the floor.

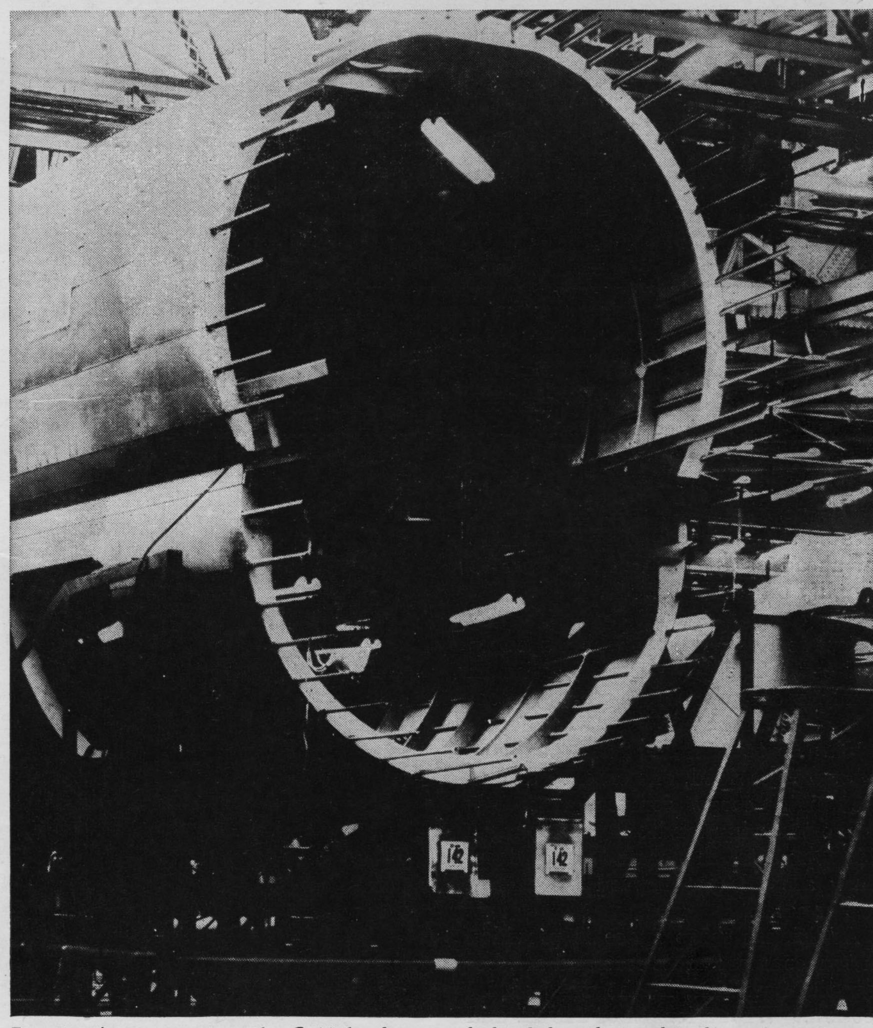


Fig. 1. A cross section of a C-46 fuselage just behind the pilot's cabin shows this construction: two circles with intersection at the common chord line formed by the cabin floor separating the main and lower cargo compartments, designed to provide an ideal structure for cabin pressurization without presenting an excessive frontal area.

Development of the plane from a peacetime passenger transport to a task force aircraft brought redesign even to the main cargo loading door (5) through increasing its size to a 96-in. width and with depth at fore edge of 78.5 in. and 66.5 in. aft. The reason for the greater height at the fore edge is that the floor just inside the door is installed so that it is level when the plane is in three-


Fig. 2. Looking aft in the main cargo compartment, which provides approximately 2,300 cu ft of cargo space. The floor adjacent to the cargo door is level to expedite loading and unloading when the craft is in three-point position. The main portion of the floor is but 9.5 deg from the horizontal when the craft is on the ground; loading is further facilitated by a hydraulically operated loading winch set at the fore end of the compartment. Note four tracks, designed to handle the aircraft engines in wheeled dollies.

Following the basic design, which included visibility and comfort as prime considerations, the pilot's cabin provides space for two pilots and a radio operator. Both pilots' seats have fore-and-aft travel of 9¼ in. and can be raised or lowered 5¼ in. The windshield (8) follows the fuselage contour, its outer surface being flush with the skin. Downward vision is enhanced by extra side panels, the lower edges of which are about level with the seats.

All engine controls are grouped on the pedestal between the pilots. Flight, engine, and navigation instruments, all "black-lighted," are grouped in four panels, two on each side of the automatic pilot. Each panel may be removed individually, or the panel as a whole may be taken out, for ease and speed of maintenance. Instrument maintenance from the back of the panel is facilitated by the fact that the fuselage nose section can be removed easily, affording plenty of working space on plumbing and wiring.

point position. This level portion, created to facilitate loading, extends 18 in. ahead of and behind the door to simplify cargo handling further.

The cargo door is divided vertically in two sections, both of which open up and out. The forward section has an auxiliary door opening in and up, measuring 55 in. high by 30 in. wide.

Three extra 20.5- by 26-in. auxiliary exits are provided, one on each side of the main cargo compartment just above the wing, and one on the right side opposite the main cargo door. They are released inward by pulling two handles.

Additional cargo space is provided in two compartments fore and aft, below the floor line, in the wing center section. With a length of 148 in. and an average center headroom of 44 in., the fore lower compartment (6) has a volume of 197.2 cu ft and a 3,450-lb capacity. The aft compartment (7), measuring 143 in. in length and of the same average headroom, has a volume of 258.4 cu ft and capacity of 1,750 lb. Both compartments are accessible from the ground through doors 3 ft 5 in. wide and 2 ft 8 in. high, both on the starboard side of the fuselage.

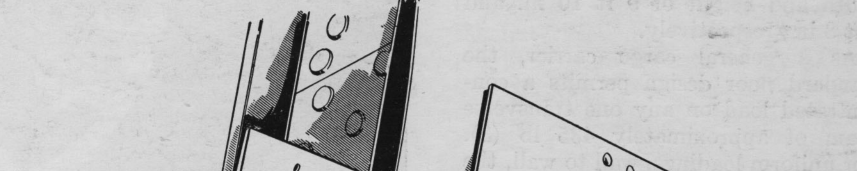


Fig. 3. This detail sketch illustrates the method of tying together the circular segments through beams which serve an additional function as main cargo-compartment floor supports.

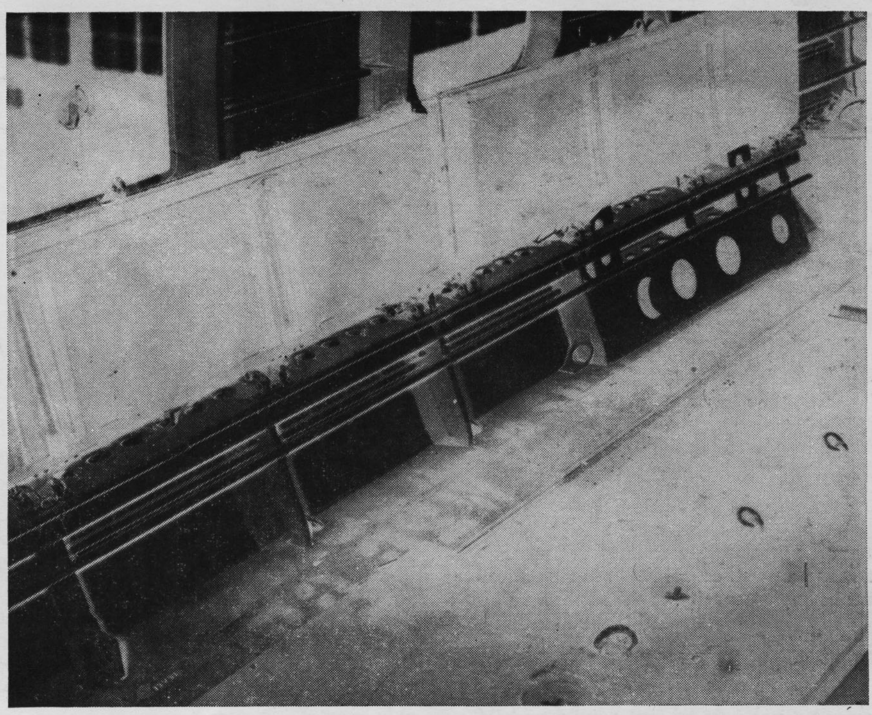


Fig. 4. Four sets of cargo tie-down fittings are available in the Commando, three of which are shown here. At the lower left are special engine eyebolts, which may also be used for general cargo. The second set is at the juncture of the floor and fuselage side, with the third set in the fuselage bulkheads just above the folded troop seats. In addition, two more rows are set in the roof, 25 in. on either side of the center line. All tie-down brackets are designed to use $\frac{3}{4}$-in. rope or 1$\frac{3}{4}$-in. webbing straps.

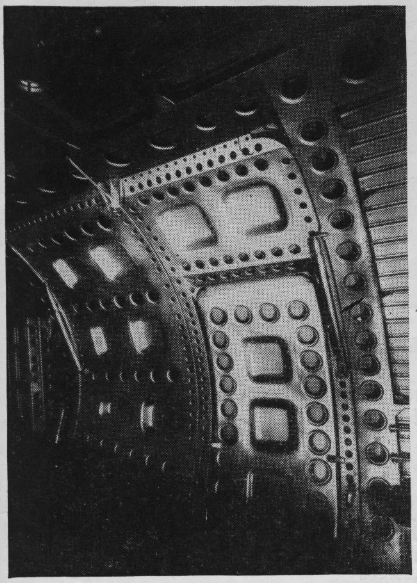


Fig. 5. Light weight is combined with strength in the construction of the 96-in. main cargo door, which swings out and up for loading. The door is divided vertically so that two segments can be opened independently. The forward segment contains an auxiliary passenger door, measuring 30 in. in width by 55 in. in height, hinged at its leading edge.

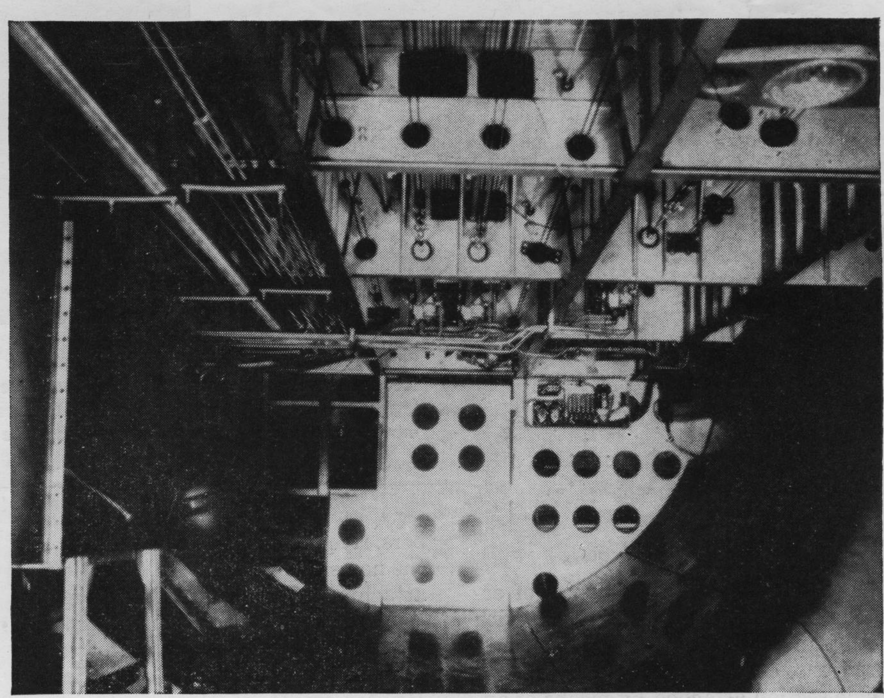


Fig. 6. The fore lower cargo compartment, which is accessible in flight through a trap door in the floor just behind the pilot's seat, has a capacity of 3,450 lb and volume of 197.2 cu ft with average center headroom of 44 in. As in the aft compartment, control cables and plumbing are easily accessible for maintenance. Both compartments are reached from the ground through doors 3 ft 5 in. wide and 2 ft 8 in. high.

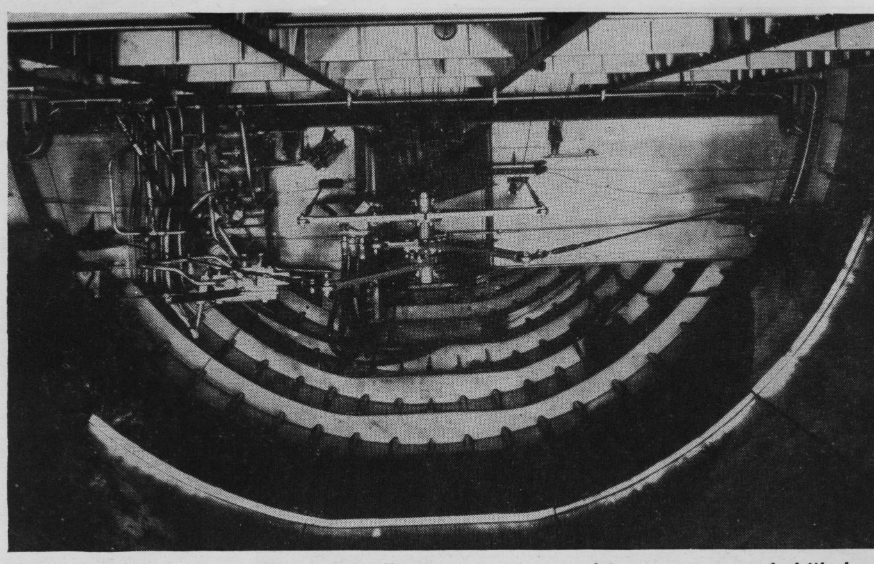


Fig. 7. Additional cargo space, as well as maintenance simplifications, is provided "below decks," the aft compartment having a capacity of 1,750 lb, a volume of 258.4 cu ft, and an average center height of 44 in. Looking forward is the rear spar of the center section with aileron controls, hydraulic boost, and rudder cables all readily accessible for both inspection and maintenance.

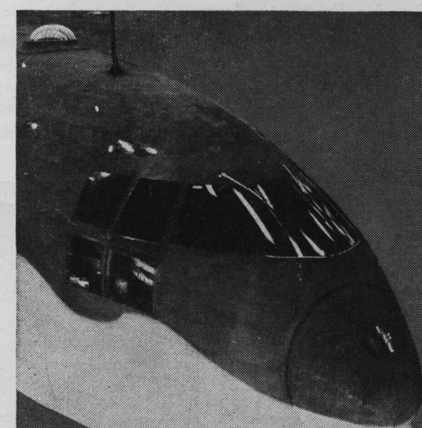


Fig. 8. The windshield follows the contour of the fuselage and is provided with both anti-icer unit and mechanical wiper. Flush riveting is employed on all "drag-sensitive" areas (approximately the forward third) of the fuselage, wings, and empennage groups. A removable nose tip for instrument maintenance is clearly outlined.

Vickers-Viking

The fuselage of the Viking is of orthodox stressed-skin construction with oval frames, identical except at certain positions, carrying stringers of beaded angle section attached by means of angle plates.

Ordinarily, there is no skin attachment to the frame flanges. Where they are required, local boundary members, riveted to the frames and carrying the necessary skin flanges, provide skin attachments in highly stressed regions, as in the pilot's compartment (1).

Flush rivets ⅛ in. in diameter are used to secure the skin to the stringers. Reinforcement of skin-panel circumferential joints is provided by a shallow-channel section butt straps picking up two staggered rows of countersunk rivets in each skin. Longitudinal lap joints are made on stringers and pick up single rows of mushroom-head rivets.

The floor beams consist of lipped channels with large flanged lightening holes. The attachment of beams to frames is by only eight rivets at each end, inserted through the frame and floor beam without corner gussets or reinforcing plates. Z-section members attached to the frames by bent-up lugs

and provided with skin attachment flanges support the longitudinal edges of the floor covering.

The fuselage frames of fluted-channel section are constructed in four quadrants with reinforced butt straps at top, sides, and bottom. The quadrants are rolled and formed in a single operation by machine.

The rear portion of the aircraft's fuselage carries the empennage attachments. It is constructed as a separate unit consisting of a section embracing three frames of deep and heavy tapered-channel section, with the tail-plane spar incorporated in the structure. A triangular opening for the tail wheel, bounded by a pair of longitudinal-channel members picking up all three frames, interrupts the continuity of the middle frame to which the spar is attached. A diaphragm, located immediately in line with the forward end of the opening and secured by its flanges to the longitudinal members, provides reinforcement in the vicinity of the interrupted frame.

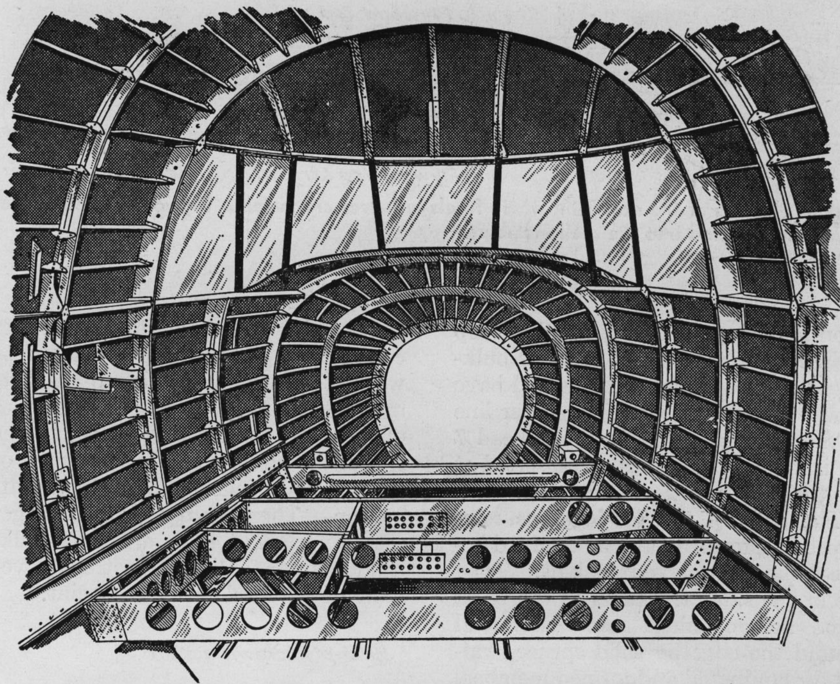


Fig. 1. Interior view of a Vickers-Viking 28- to 30-place transport, showing the fuselage construction at the pilots' compartment. Skin attachment is provided by local boundary members riveted to oval frames. The floor beams are of lipped channels with large flanged lightening hobs.

De Havilland Mosquito

The complete Mosquito fuselage (1) is of balsa-plywood sandwich construction, the 0.437-in. balsa being compressed between two 0.062-in. three-ply spruce or birch skins. The weight of balsa wood, which varies greatly from 5 to 30 lb per cu ft, averages about 9 lb per cu ft in the Mosquito through careful selection.

The kind of plywood and the direction of the grain are changed to suit stress conditions. In the section from mid-cockpit forward to the bombardier's window, three-ply spruce is used. Here the fuselage has a sharp compound curvature, requiring narrow strips, taper cut, with two plies lengthwise and one transverse.

From the forward spruce-plywood section back to about 6 in. aft of the bulkhead 5, three-ply birch is used. This forms about 60 per cent of the fuselage. It is laid on with the grain running longitudinally. Bomb-bay doors included in this section, as well as the bomb-bay side panels beneath the wing, the latter having a diagonal grain instead of longitudinal. The door panel of the bomb bay has inside and outside skins preformed before assembly. The underwing section is glued in place with the rest of the fuselage and cut out after the finished half fuselage is completed. All other panels, in as large sheets as possible, are carefully scarfed together and glued in place.

The rear fuselage section, which includes bulkheads 6 and 7, also is made with birch plywood with grain laid on diagonally better to resist torque of the empennage. All vertical joints between panels are arranged to be not less than 6 in. away from the bulkhead. All longitudinal joints are made to lap over the spruce stiffening stringers.

The fuselage is built up in two halves on separate right- and left-hand jigs. The wing openings on each side, the cockpit aperture on the top, the dinghy compartment opening, and the ends of the fuselage are left open during construction. The top and bottom edges of each half are reinforced with spruce-laminated members. Where the two multi-ply strips bear against each other, V grooves in half accurately center the edges but are not glued (2). The inner and outer plywood skin is stepped off each side of the joint so that a lap strip of equal thickness to the outer skin can be applied. This is glued and tacked into place, both inside and outside the assembled fuselage. It is further strengthened inside by a 0.12-in. three-ply birch strip twice as wide as the first one applied.

Union of the two halves does not de-

Fig. 1. Fuselage construction, showing the general arrangement and location of the bulkheads.

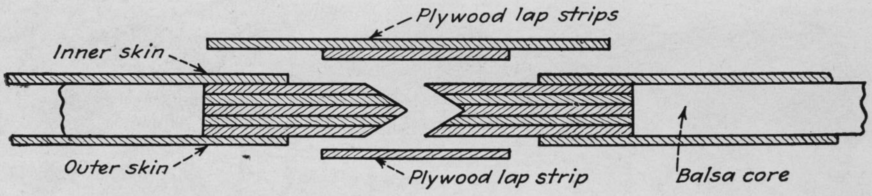


Fig. 2. Details of the skin joint where fuselage halves are mated. Plywood lap strips are glued and screwed into the shell members.

pend entirely on bonding of these top and bottom edges. Of the seven bulkheads, six are made in halves and have a butt joint on the vertical center line of the fuselage. The rear bulkhead 7 (3) is made in one piece and inserted at the time the fuselage halves are mated.

The ends of the fuselage are reinforced and formed half circles glued between the inner and outer skins. They are of the same thickness as the balsa core. All openings are reinforced around the edge by solid spruce, walnut, or laminated and formed members (4). In addition, two stringers are built into each half and extend from bulkheads 3 to 7. These are buried between the skins in the balsa core. The only external stiffening member is a long half-round piece on the left side of the fuselage rear above the rear entry door. The upper stringers tie into bulkhead 3 and run forward about 1 ft to include the rear end of the wing pickup member.

The bulkhead assembly method is the same for all except bulkhead 7. Intermediate bulkheads are all located in their proper stations in the fuselage build-up mold, and the inner skin is stretched over them. Glue and screws are both used for attaching skin to the bulkhead. There is a 0.12-in. three-ply screw strip approximately double the bulkhead thickness glued to the inner skin, through which are driven screws to secure the bulkhead.

Formed laminated-spruce semicircular pieces of the same width as the bulkhead next are glued and screwed on top of the first strips and also are screwed directly to the bulkhead. The combined weight of the two pieces, attached to the bulkhead but outside the inner skin, is equal to the balsa core. These bulkhead reinforcements are stopped off at the stringers.

Forward of bulkhead 2, the front floor reaches from side to side of the fuselage, and when joined with bulkhead 2 and the instrument panel structure, it greatly stiffens the front section.

Bulkhead 3 carries at its outer lower corners the heavy reinforcements to which the lower wing pickup brackets are bolted. These are attached not only to the bulkhead but also to the side of the fuselage and forward ends of the lowest stringers built into the aft section. These stringers are of larger section for about 40 in. aft of the bulkhead in order to distribute stresses over more of the fuselage at this point.

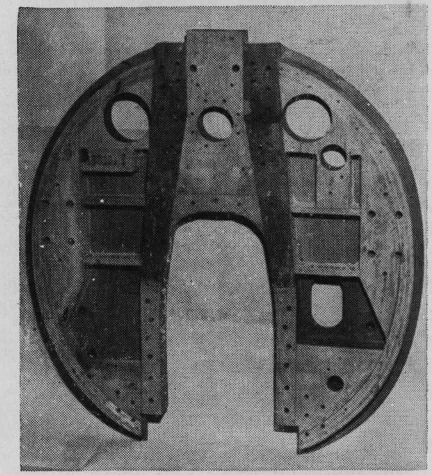


Fig. 3. Detail of rear bulkhead 7 looking forward. The left half is shown with the plywood facing removed to reveal material and structure.

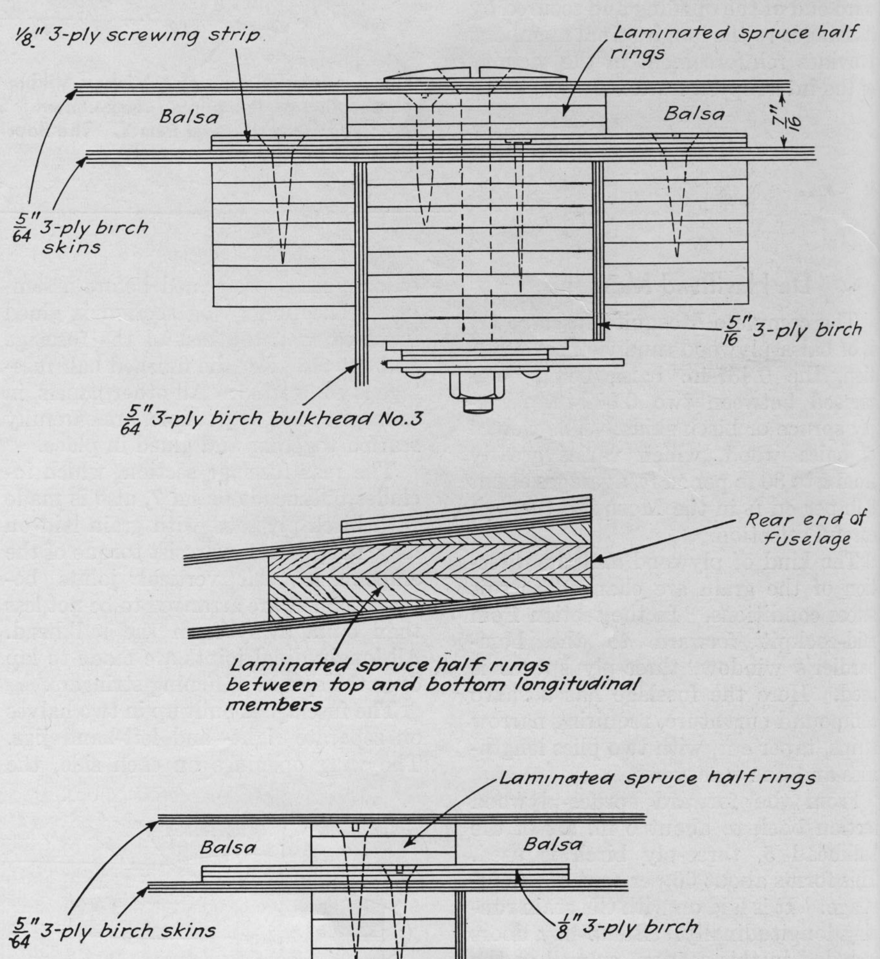


Fig. 4. Methods of reinforcing monocoque walls at the bulkhead.

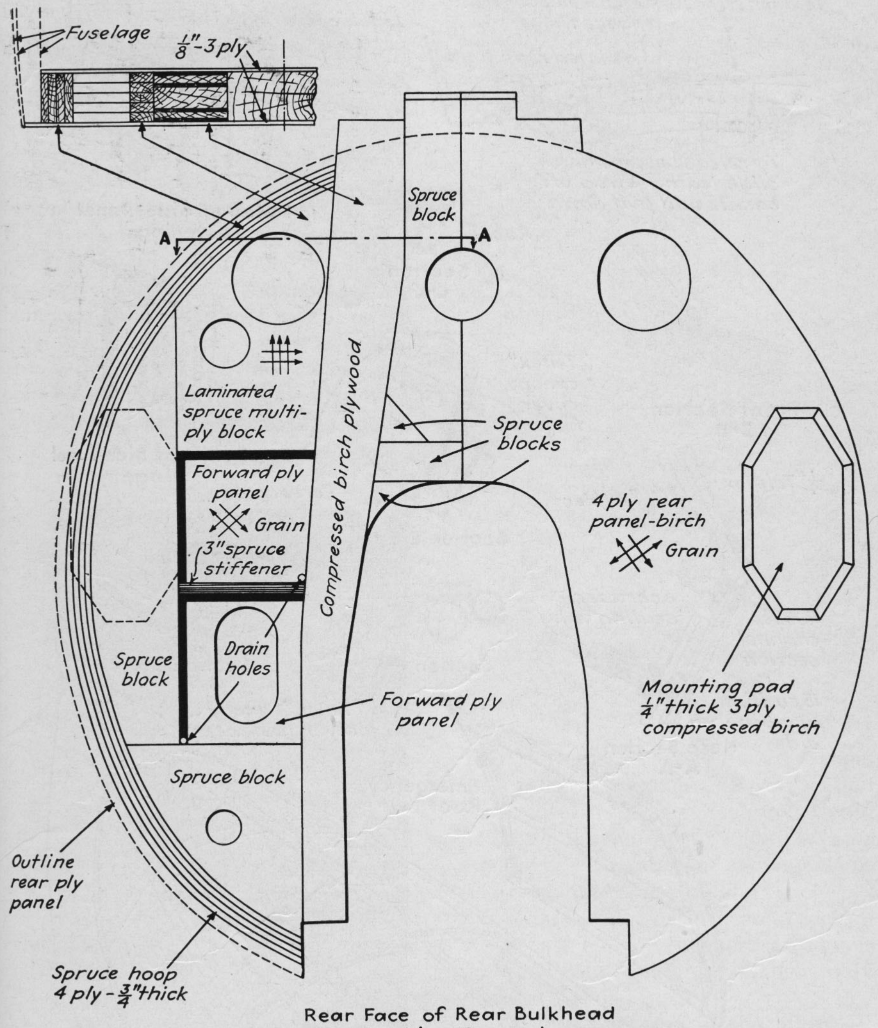


Fig. 5. Rear face of the rear bulkhead looking forward.

The heaviest load of any member in the fuselage probably is carried by the rear bulkhead (5), for it supports the tail plane and tail wheel, also sharing the fin and rudder reactions with bulkhead 6. It is a composite structure built up of many types and forms of wood. The outer edge is made from a four-ply spruce half ring. The two members running vertically on either side are compressed birch plywood. They support the rear bracket of the fin at the top, while at the bottom they carry the tail-wheel bracket and tail-plane rear spar braces. The whole unit is tied together by 0.12-in. three-ply birch facings glued to each side.

The side panels which finally close the opening below the wing are held in place by a securely bolted 2.0- by 0.12-in. aluminum plate which covers the front end gap. At the rear end, two 1.62- by 0.06-in. aluminum strips are placed on each side of the panel and held with through bolts. They close a gap or expansion joint about 0.37 in. wide at the rear end. The panels are only a closure since the wing is the structural member which ties together the fore-and-aft lower edges of the fuselage.

When completed, the entire fuselage is covered with Mandapolam, an airplane fabric that is stretched with dope, then painted.

The method of fastening equipment and attachments to the inside of the perfectly smooth fuselage is ingenious (6). Templates are provided for locating bracket holes into which bakelite-molded ferrules are glued. Each ferrule has a brass nut molded inside of it and a 2-in. diameter two-ply birch disk glued to the outside end. When glued and bradded into place, these nuts make a secure foundation for any attachments.

The cockpit canopy (8) is built up on a welded-steel tubular frame with an angular flange along the lower edge to fasten it to the fuselage. An escape opening is in the top with a quick-release latch. Removable windows at each side of the V windshield provide direct vision if necessary.

The triple-plate antifogging V windshield windows incorporate a unique system for exhausting the air space between them. Each is connected by a tube with a Schrader air valve. Air can be sucked out, but its return is prevented by the valve. A small bladder attached to the outlet tube provides the exhaust system. It expands as the ship climbs, thus sucking the air out of the hollow windshield. A tube of silica gel is inserted in the suction line to remove moisture contained in the air within the windshields.

The wing pickup members are built up from 0.4-in. laminated spruce with the grain running lengthwise in all plies. The pickup member extends forward from bulkhead 3 to the point where it is bolted to the fitting that is mounted on top of the front main wing spar. The adjustable fitting which is bolted to the wing clevis bracket is secured to the

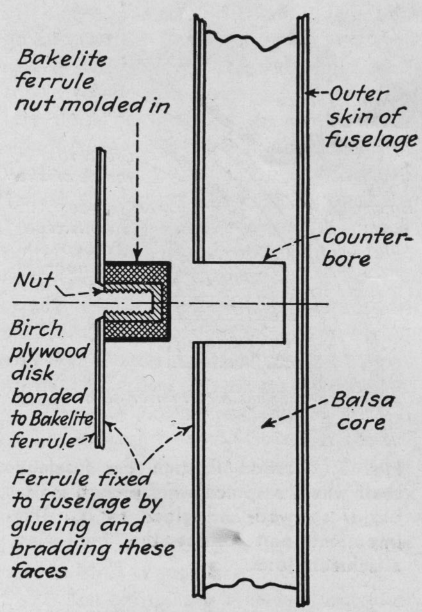


Fig. 6. The unique method used in fastening the accessory mounting units in the wall of the fuselage.

wooden pickup member by top and bottom plates. The pickup at this point also is secured to the fuselage side by five through bolts with a metal compression plate inside the fuselage as a bearing for the nuts.

The wooden pickup member is carefully fitted to the inside of the fuselage, and then screwed and glued to the inside skin (7). A formed four-ply spruce backing strip forms the core of the fuselage behind the pickup member. This is glued and screwed in place before the outer three-ply skin is applied.

A serrated block, tapped out for the adjustable pickup fitting, is secured between the top and bottom metal plates by through bolts. Transverse grooves relieve the holding bolts of any shearing stresses in the fore-and-aft directions. For adjustment, a sleeve is threaded inside and out with a hex nut on the end. As the threads are of opposite hand, the sleeve acts like a turnbuckle. Check nuts are provided on both sleeve and bolt so that the whole nut can be locked when adjustment is complete. The wing holding nut is slipped in place through a hole provided in the fuselage skin and secured by a castellated nut.

Scupper holes are provided between ribs and spars or similar members in the fuselage for drainage, of vital importance in a wooden plane. Holes with flush eyelets are provided at all drain points.

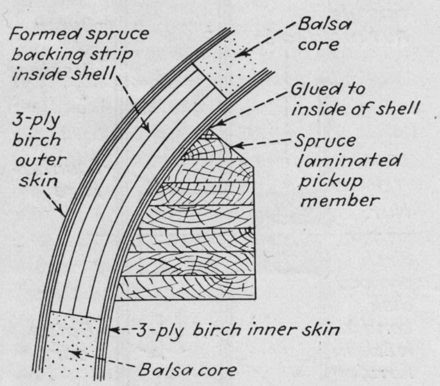


Fig. 7. Section through the fuselage shell where a spruce wing pickup member is screwed and glued to it. This important part carries the front-wing attachment joint.

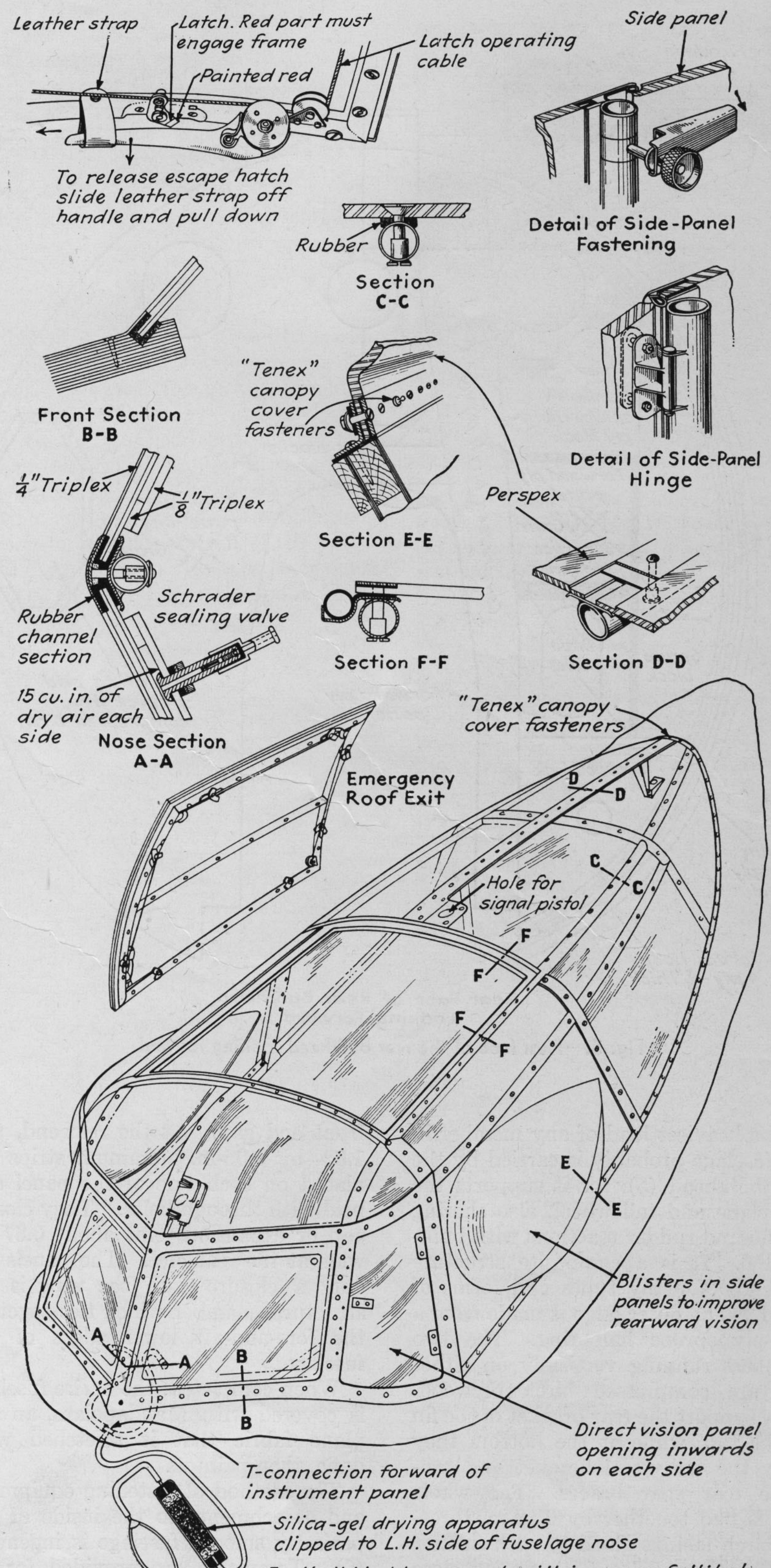


Fig. 8. Construction of the cockpit canopy showing the use of air space in the triple-plate windshield; also the method of evacuating air to prevent fogging in cold or high altitudes.

Messerschmitt Me-262

In the Me-262 jet-powered interceptor, the entire nose section attaches to the mid-fuselage in a simple but effective manner. At each lower corner is a 1-in. (approximately) high-tension steel bolt fastening it to the solid web bulkhead of the mid-section (1). At the top, some 6 in. from the center line, are two 1½-in. steel tubes, also bolted to forged fittings on the mid-section bulkhead and extending forward to the bulkhead at the front end of the gun access doors. Both these tubes are built as turnbuckles so that alignment adjustments can be easily made.

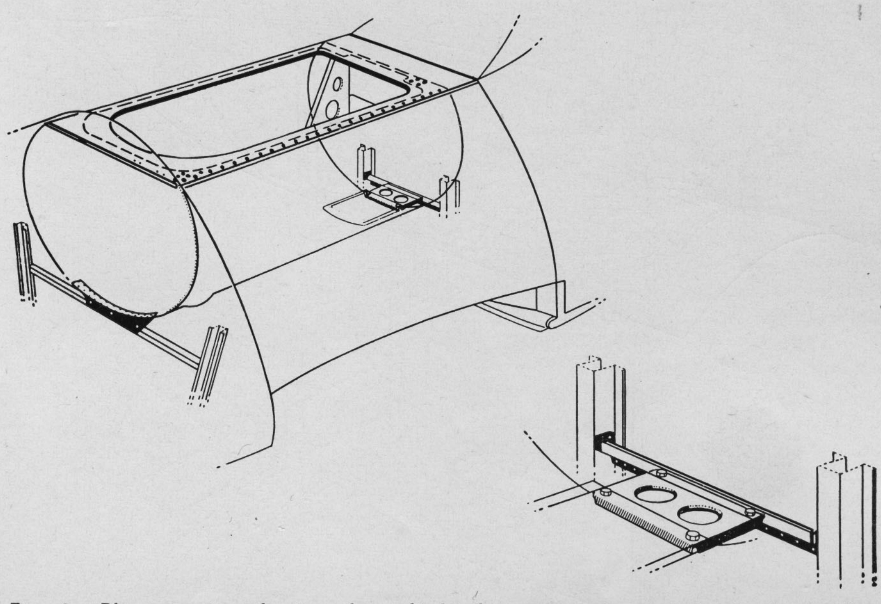


Fig. 2. Phantom view showing the cylindrical-section cockpit in the fuselage. This "liner" section is designed for pressurization, but the craft and reports studied reveal that the Nazis did not actually pressurize the Me-262 in operation.

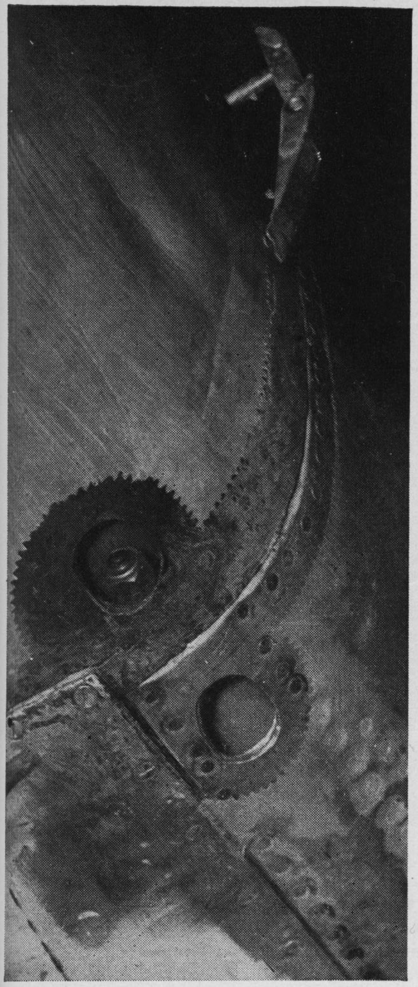


Fig. 1. View from below the fuselage connection, showing how through bolts—one on each side—join the nose to the mid-fuselage section. The afterconnection is complete; access holes are covered with doped fabric. At the top is one of the quick fasteners by which the cowling over the gun compartment is held in place.

Thus it would be possible for a trained crew to change a damaged nose section in the field in short order, or it would be a simple matter to install a nose equipped with different armament or photoreconnaissance units.

The Me-262's fuselage cross section at the aft end of the nose section is practically an equilateral triangle, only slightly rounded out.

The first bulkhead in the mid-fuselage section is solid-web aluminum alloy with six vertical and two horizontal hat-shaped stiffeners.

At a point 16¾ in. back is a channel-shaped former, flush-riveted to the skin, and 16 in. farther aft is another solid-web bulkhead with vertical and horizontal hat-shaped stiffeners. Practically all the space between the two solid bulkheads is taken up by the fore fuel cell. The bottom panel of this section consists of a waffle grid, double-stressed skin, 34¾ in. long and 55 in. wide. The panel is attached to the fuselage by flush screws and captured nuts, the same system employed in the FW-190 panel beneath the fuel cells. Interchangeability of these panels evidently was not much of a consideration in Me-262 production, for the screws were set approximately 1¾ in. apart but with variations of as much as ¼ in. and considerable misalignment.

Only one channel-shaped former extends from the cockpit rail to the bottom of the fuselage at the cockpit which is, in effect, a horizontally disposed cylindrical section with part of the wall sliced off. This "cockpit liner" was designed for pressurization, but the craft examined had no means of developing pressure (2).

The cockpit canopy (3) consists of two rounded plastic-glass sections mounted in a frame with flat fore-and-aft pieces and tubular base. It pivots on the right side for entrance and exit, and it can be locked closely only from the inside by a lever which drives pins into holes set in the base of the windshield frame and the turtleback section. A 16-mm head and shoulder silhouette armor section (4), which extends up and over the back of the pilot's head, is bolted to the canopy frame just ahead of the turtleback section.

The pilot's seat is adjustable only up and down on a parallelogram frame, and it is locked into position by a lever under the front of the seat which engages a pin in ratchet teeth. Unlike earlier German craft, the Me-262 has no bungee cord to facilitate moving the seat. The upholstered back of the seat is held in place by two clip springs to facilitate removal for access to the battery behind the seat frame.

No armor plating is incorporated in the seat itself; instead, it is attached to channel-shaped vertical and horizontal stiffeners riveted to the solid aluminum

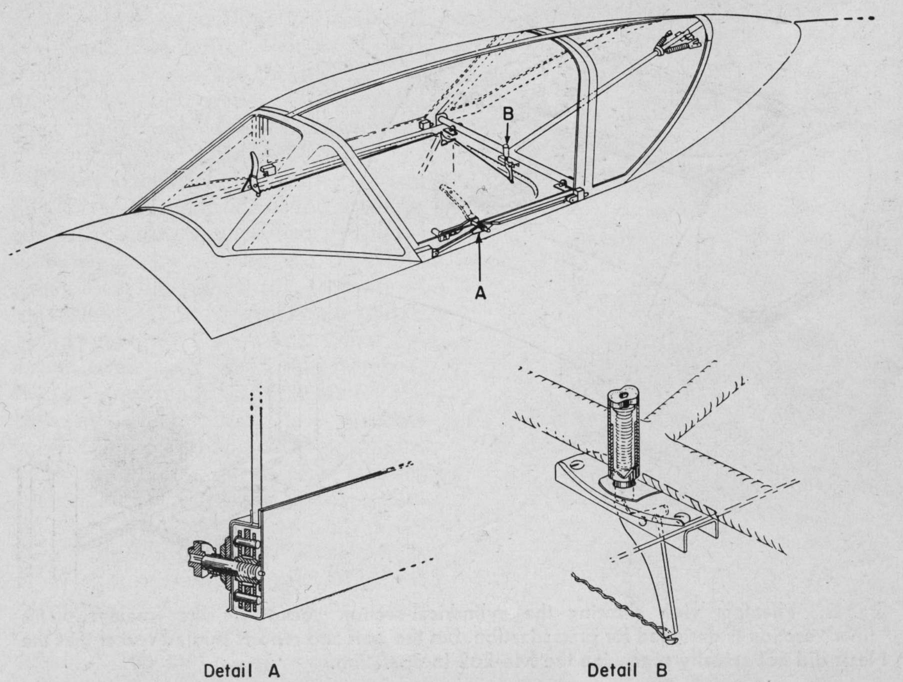


Fig. 3. Detail sketch of the cockpit canopy, showing the jettison lever on the pilot's right and the locking lever at his left. The front windshield panel is 3½ in. thick bulletproof glass. No side or bottom armor is provided.

alloy bulkhead which begins the aft fuselage section and forms the front panel of the rear fuel cell space. The bottom skin panel for this section measures 35½ by 60 in. and is similar in construction to that under the front cells. In the middle of this fuel cell, some 17¾ in. back, is a former which is a built-up double-channel section up the sides to the second from center-line stringer, from which point it is single channel. Like most others, this former has cutouts for the stringers.

In this connection, it is interesting to note that the Me-262 employs only hat-section stringers, one along the top center line aft of the cockpit; five along the sides (with one ending at former 14); and five along the bottom (two outermost ending at former 15), there being no longerons.

The bulkhead forming the aft end of the rear fuel cell is a solid web but is sheet steel of approximately .080 gauge.

An unusual construction feature is found throughout much of the aft fuselage section (5), where the formers are made of the aluminum skin sheets themselves. Skin sheets are formed to the fuselage contour, then the aft ½ in. is joggled to the thickness of the metal itself—about .050—then bent inward to form a channel or J section. The next skin is lap-jointed and flush-riveted in place.

Immediately aft of the cockpit the fuselage shape starts its change from triangular cross section to a very narrow elliptical section only 2 ft wide at a point just ahead of the stabilizer.

The tail cone construction is, in some respects, quite like that on the FW-190. It bolts to the aft fuselage section with the joint larded (at least on some planes) with liberal quantities of filler and covered by a doped-fabric strip in a vain attempt to get a smooth finish.

The former aft of the joint is a built-up ring riveted to a steel I-beam section which slants aft 47 deg from the vertical and extends up some 2 ft above the fuselage top to form the lower part of the front fin spar.

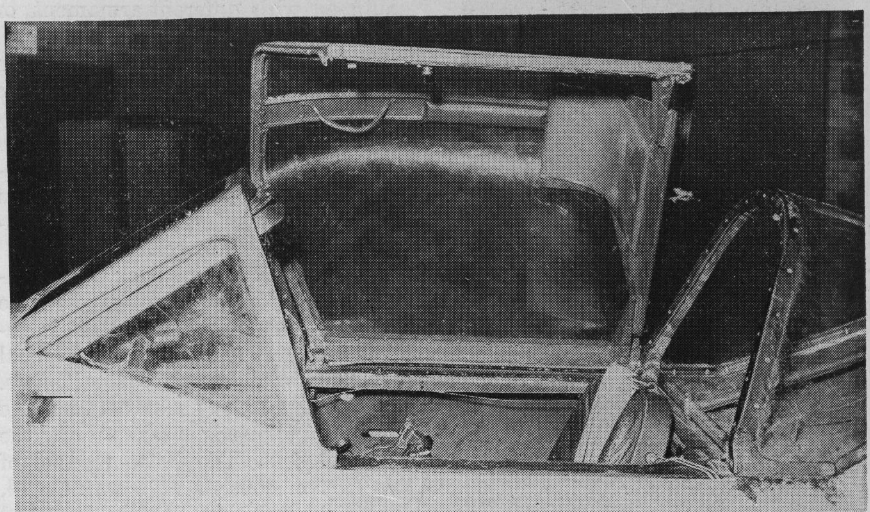


Fig. 4. Me-262 canopy open, showing the jettison lever and cabin at the pilot's right. Note the curved silhouette armor plate which fits over the pilot's head. Evidently this was a modification of the original design, for basic plans show no such installation. At the windshield base at the left can be seen the cockpit ventilating scoop. Apparently this was also a last-minute modification, one which showed workmanship far below normal German standards.

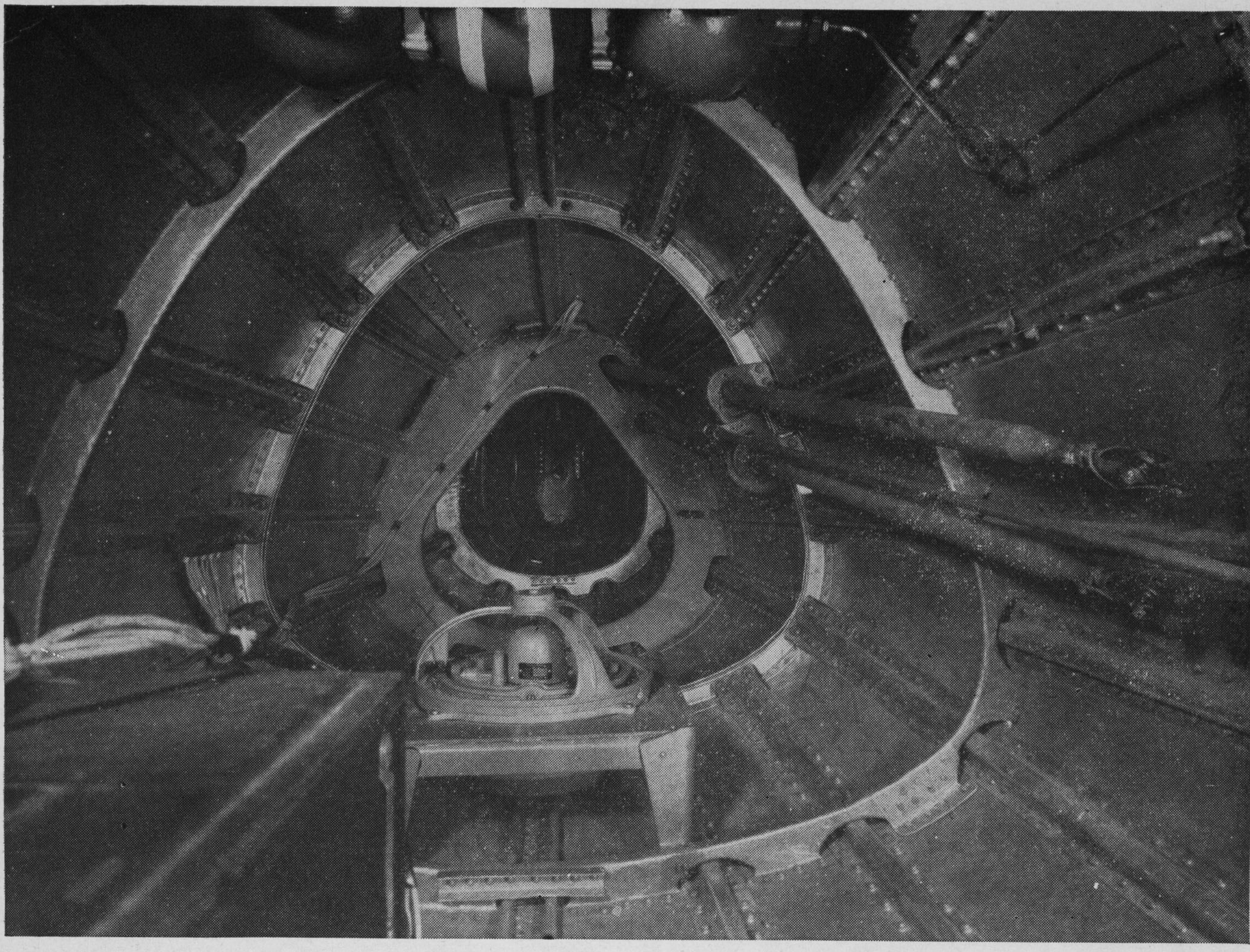


Fig. 5. Inside the aft fuselage, with radio in the left foreground, are seen a master compass in the center, oxygen bottles at the top, and elevator, rudder, and rudder trim tab torque tubes at the right. Shown are typical stringers which completely replace longerons. The formers in this section are integral parts of the skin sheets, which are joggled to the thickness of metal for the lap joint, then bent inward to make a J or channel section.

Douglas A-20

The fuselage of the A-20 is comprised of five major sections: attack or bombardier nose, pilot's cockpit, bomb bay, gunner's compartment, and tail compartment.

Keying much of the A-20's adaptability to varied types of missions, the nose sections are interchangeable, one with the other or from plane to plane. Changing them is merely a "wrench and screw-driver job" that can be done in the field by two men in 6 hours or less.

In general appearance, there are two kinds of noses—bombardier and attack—but actually there are several different kinds of attack types, each mounting a different combination of guns or night-fighting devices, with the necessary variations in structure.

The bombardier nose (1) is secured by only 6 bolts to the fuselage, while 10 are required for the attack noses. Of these, 8 are spaced around the perimeter of the attach ring, and 2 are located inside the outer line of bolts. Trunnion fittings at the forward end of the nose and swing links toward the after end of the structure form supports for the four center fixed guns. The two side guns are supported directly on the castings attached to the nose beams.

All types of noses are identical in dimensions at the fuselage junction point, but the attack nose is 8 in. longer than the bombardier version. The latter is manufactured as a single unit, while the attack version is assembled "half shell" and then joined, much the same as is the main fuselage.

The bombardier nose is built up of formed channel sections with the forward third of the structure of formed and extruded T sections. The latter third is covered with Plexiglas, which is retained with strips and flush screws. The interior arrangement provides a bombardier seat under which are the ammunition boxes for the side guns. There is an instrument panel

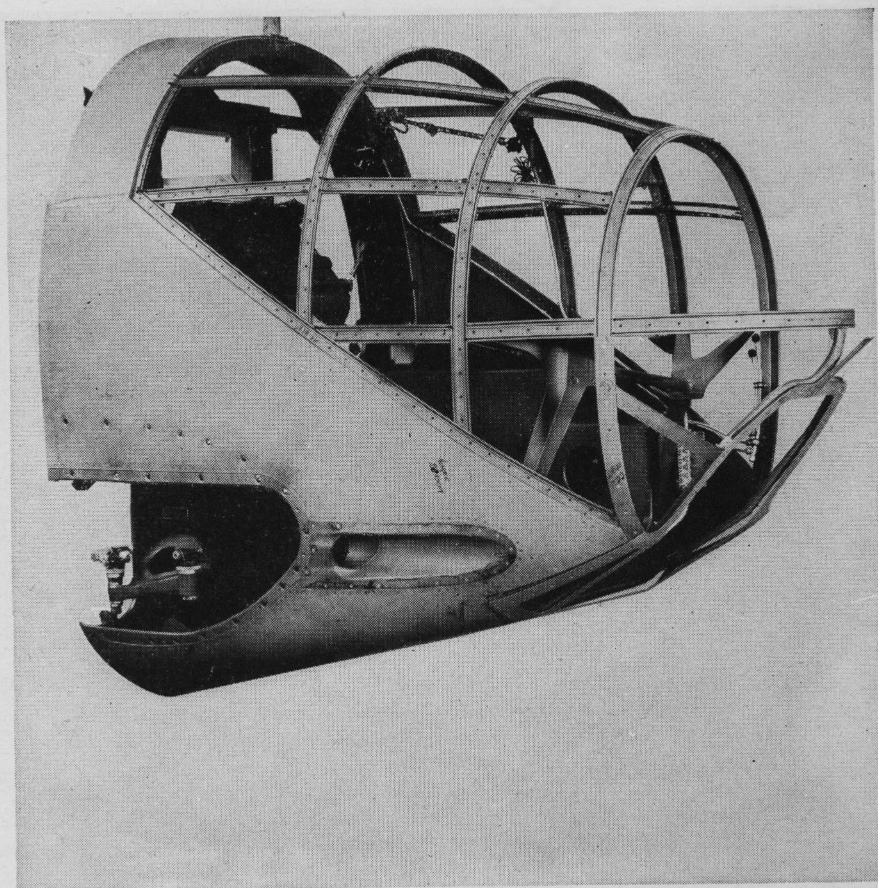


Fig. 1. The bombardier nose frame before the Plexiglas covering is attached. Note the tube for a .50-caliber gun at the side with an access door behind it. A bottom exit door is provided for the bombardier.

for various types of bomb sights and a laminated plate-glass panel for sighting.

For maximum all-round vision, the pilot's cockpit is located forward of the wing and engine nacelles. From a normal position in the cockpit, the pilot's vision is directly forward over the center line of the fuselage and exceeds 8 deg below the horizontal. Access is by means of a door in the top of the cockpit enclosure.

The wind screen is laminated plate glass and molded Plexiglas, the center panel being curved laminated plate. The side and top panels are of molded Plexiglas. Behind the laminated plate, and separately mounted in a hinge frame, is a bulletproof plate glass that can be swung away from the wind screen for cleaning.

A standard adjustable pilot's seat is provided, and a wheel on a cast-magnesium column gives aileron control, while the column operates the elevators. The wheel also incorporates the switches for gun firing and bomb release. Rubber pedals are provided with integral brake control.

The insulation of the cockpit is flameproof cloth-covered Sepack, or Resistohyde-covered kapok felt, to reduce noise.

From the nose tip to the bulkhead front end of the bomb bay, the fuselage contour represents faired lines. Beginning there and continuing to the bulkhead front end of the rear gunner's compartment and aft end of the bomb bay, a constant section is maintained. In this section, which represents about 60 per cent of the fuselage length, is the 14-ft by 33-in. bomb bay, considered unusually large for a plane of this type.

It is this constant section, plus those containing the rear gunner's and pilot's compartments, which are assembled in two longitudinal half sections, joined only after the major portion of the assembly and installation work is completed (2).

The rear gunner's compartment is located aft of the trailing edge of the wing, immediately behind the aft bomb bay. Entrance is by a side door in the fuselage bottom. The top section of the gunner's compartment is made up of two Plexiglas parts, one fixed and one movable enclosure which slides forward under the fixed section to allow access of the .50-caliber flexible upper gun. The upper gun is stowed in a tunnel immediately aft of the movable enclosure and is accessible through two doors on top of the fuselage operated from the gunner's compartment. The cockpit enclosure also can be used as an exit either in the air or in the event of landing on the bottom of the fuselage with wheels up.

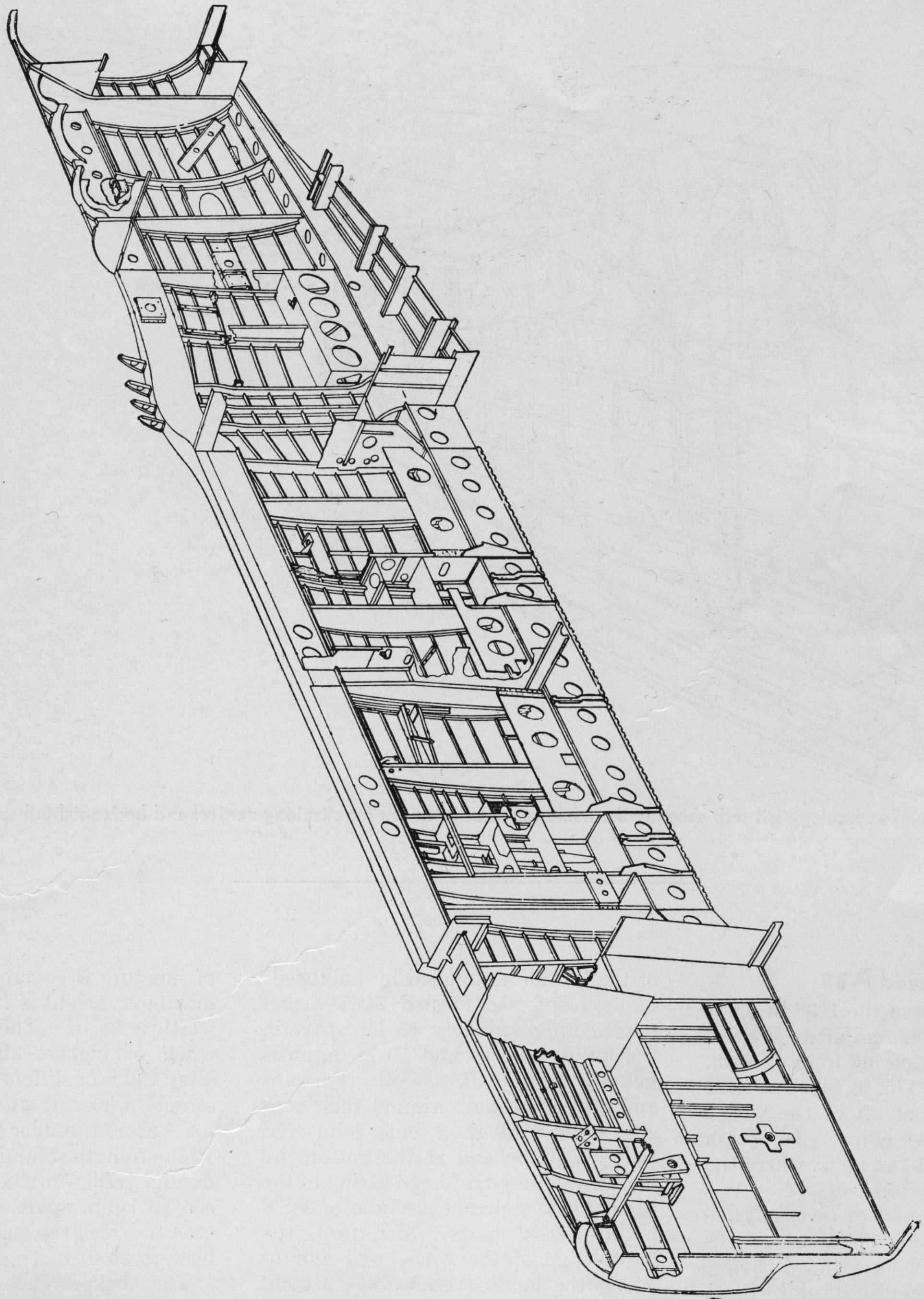


Fig. 2. The fuselage is built in two halves, joined after completion. Note the heavy frames and the large number of longerons. The bomb-bay sides are stiffened by the addition of deep panels.

The fuselage is faired upward from the bottom line of the constant section to the aft extremity to provide good aerodynamic design, to raise the empennage control surfaces above wing turbulence and slip stream, and to provide clearance for the tail section during landings with the tail down.

The fuselage tail cone (3), of conventional design, is constructed as a single unit. Frames are formed 24SO or 24ST aluminum alloy with extruded 24ST longitudinals to tie them together. The cone attaches to the main fuselage section just aft of the rear gunner's compartment by means of six internal wrenching bolts.

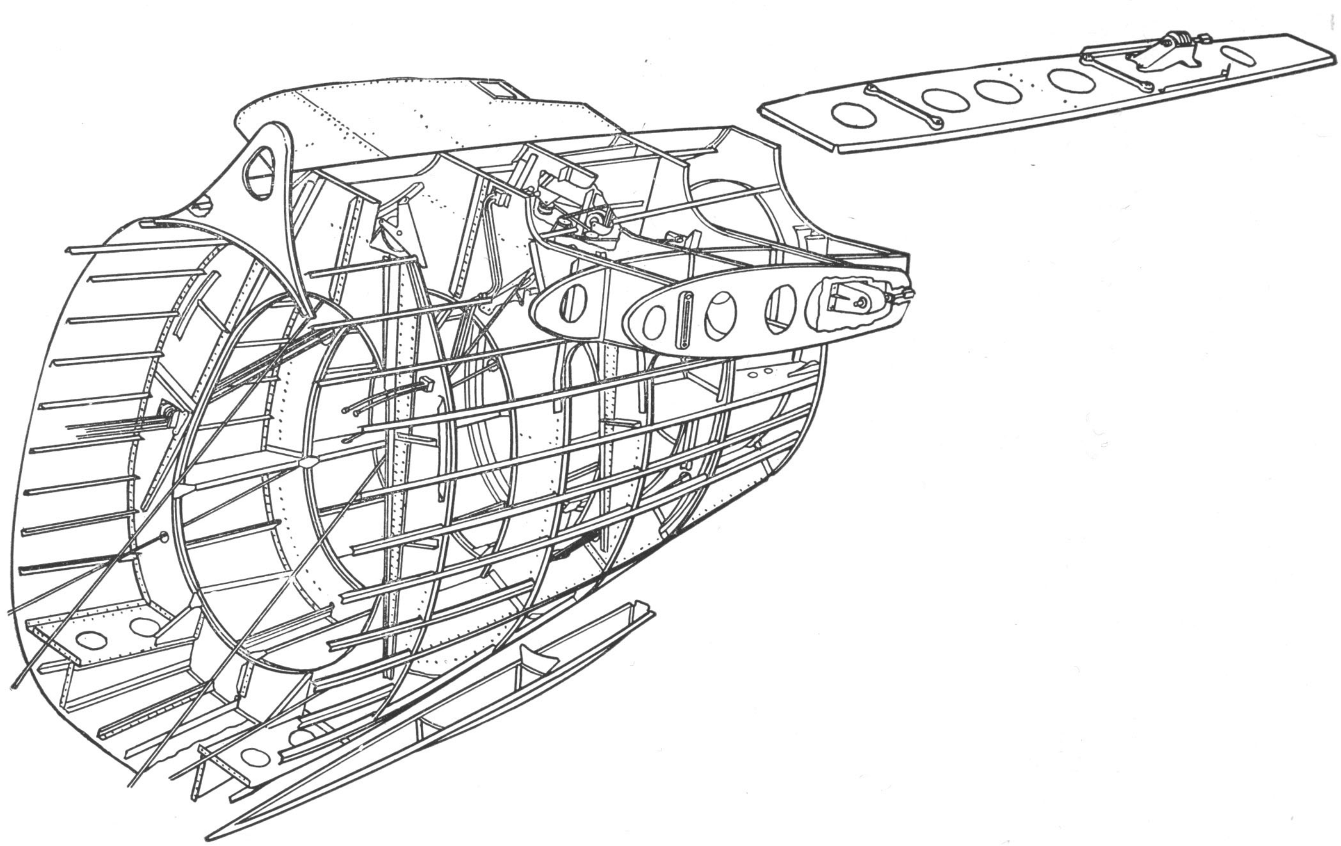


Fig. 3. The fuselage tail stub showing the framework and positions for attaching vertical and horizontal tail surfaces.

Lockheed P-38

The twin booms of the P-38 begin at the fire walls and extend aft to support the empennage, tapering from 47⅜ in. in height and 38.63 in. in width at their deepest section just aft of the wing's trailing edge, to an ellipse 13 in. high and 10 in. wide at the point where the empennage booms join.

They are built in two sections, forward (1) and aft (2). The turbosuperchargers are within the forward booms, in the upper section just aft of the junction with the wing. The main landing gear and wells are in the lower portions.

In the forward ends of the aft booms are the engine coolant radiators with their air scoops attached outside of the booms themselves. A battery compartment is included in the left boom, and balancing it in the right boom is a luggage compartment.

Boom structures are of 24ST rolled sheet of .040 gauge in the forward boom, and .032 gauge in the aft boom, and extruded bulb angles. Stiffening of the booms is supplied by bulkheads of hydro-pressed formed 24ST alclad spaced approximately 15 in. apart in the forward boom and 10 in. approximately in the aft section. Forward and aft sections are around their tops and sides through a butt joint and heavy doubler, and at the bottom by means of a pin and forged fitting in the ends of heavy channel sections of 24ST hydro-pressed parts which form the lower edge of the wheel well and to which the landing gear doors attach. The semimonocoque construction of the booms gives the required strength and is reinforced at the edges of the gear recess.

Stainless steel in considerable amounts is used in the booms, in the areas about the superchargers, and it was to fabricate this that the manufacturing divisions were forced to do considerable research and other pioneering.

The P-38's fuselage, or gondola, attaches to the center section at the plane of symmetry of the aircraft, and its line of juncture is covered by fillets. The maximum height is 72 in., and greatest width is 38 in. The fuselage is fabricated of highest strength aluminum alloy and is of stiffened monocoque construction, except where reinforcements for cutouts render this impractical. High-strength aluminum-coated, aluminum alloy-formed bulkheads are spaced 15 in. apart and form the skeleton to which the smooth alclad skin is flush-riveted.

The cockpit enclosure incorporates side panels which may be lowered by the pilot; a top center transparent panel which is hinged at the top aft edge to permit entrance of the pilot when the left side panel is lowered and which can be released instantly by a quick-release mechanism. Side panels can be opened or closed on the ground or in flight at reduced speed, and may be locked in the open, closed, or any intermediate position. The center panel of the front windshield is of bulletproof glass.

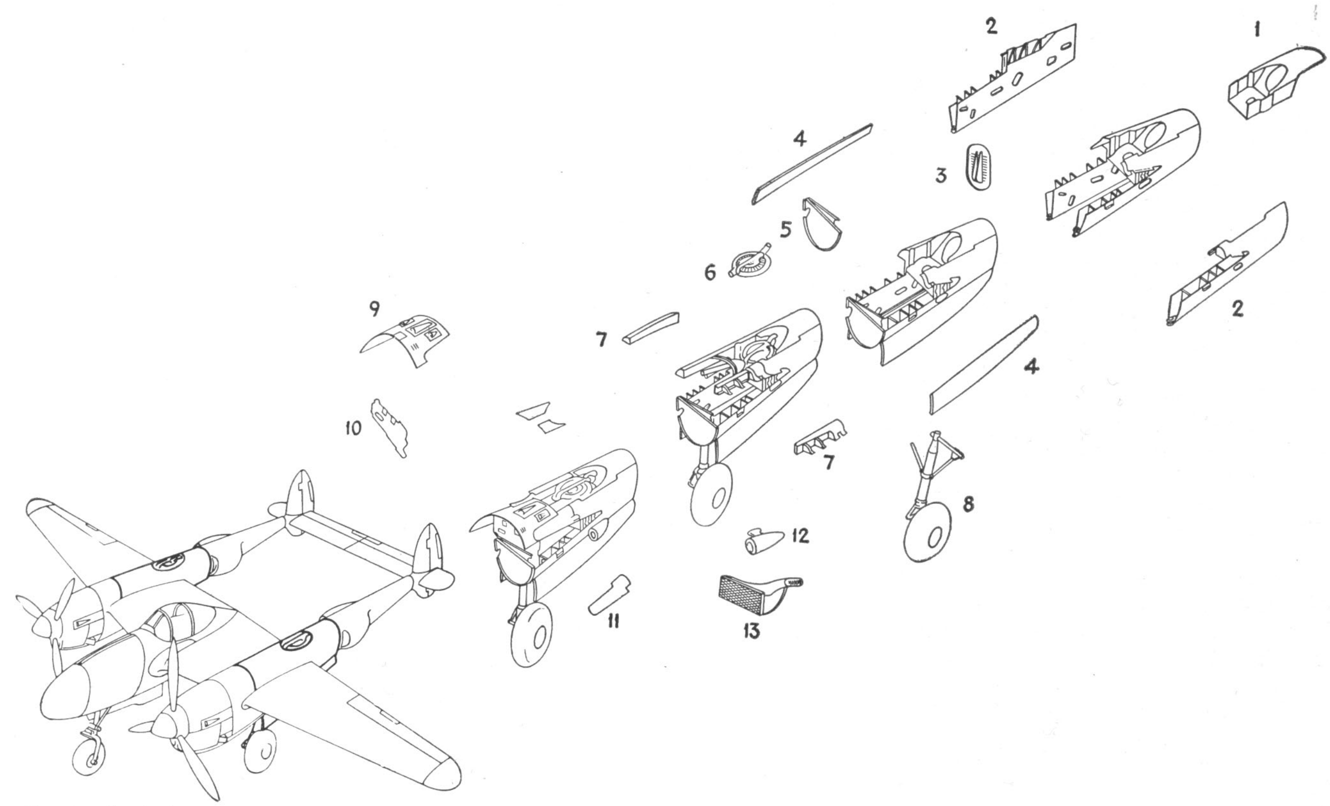


Fig. 1. Exploded view of the components making up the forward boom. Beginning at upper right, units include: (1) deck assembly; (2) panels; (3) web; (4) main wheel well doors; (5) fire wall; (6) supercharger; (7) boom angles; (8) landing gear; (9) cover; (10) main beam fire wall; (11) fillet; (12) supercharger air-intake scoop; (13) air filter.

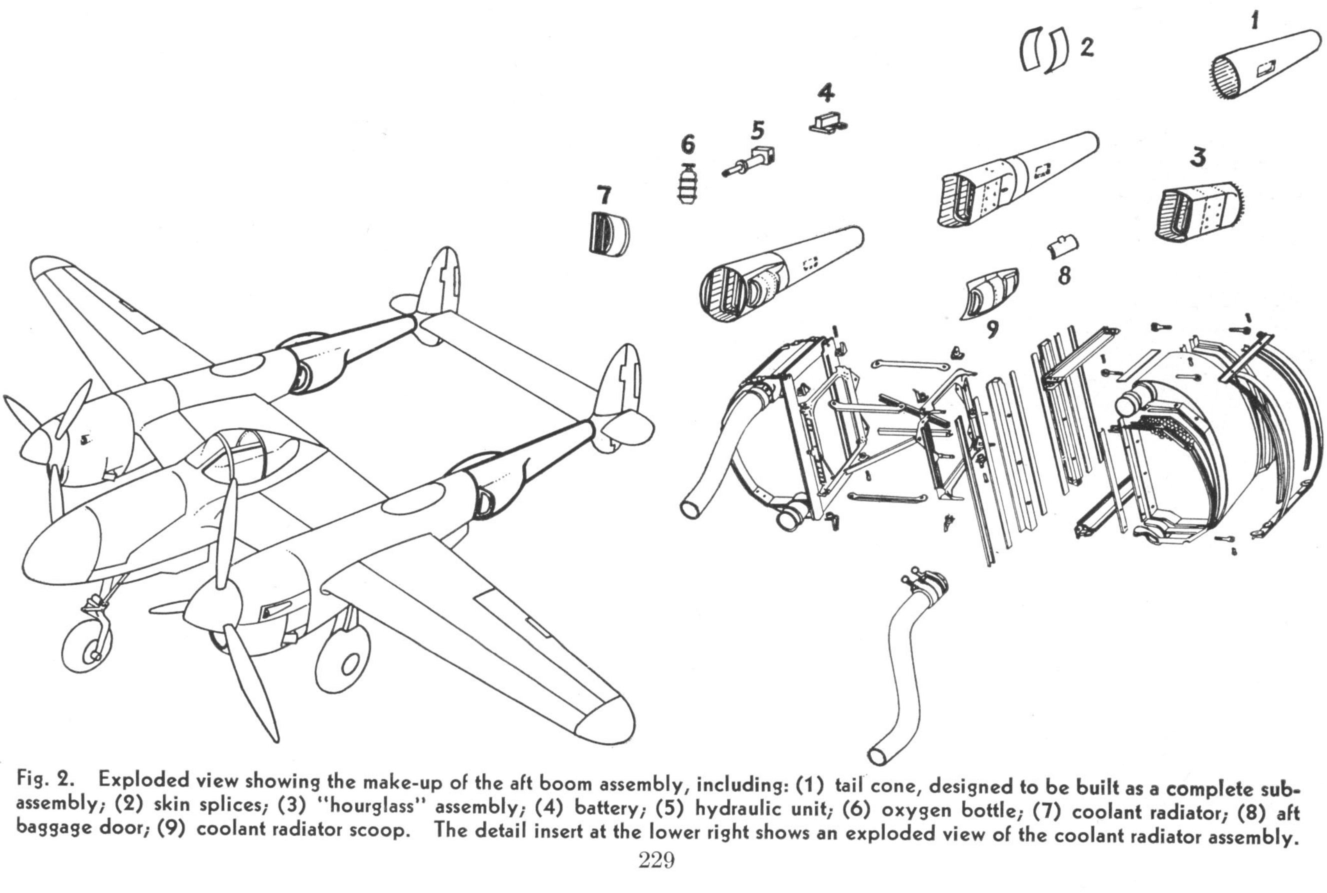


Fig. 2. Exploded view showing the make-up of the aft boom assembly, including: (1) tail cone, designed to be built as a complete sub-assembly; (2) skin splices; (3) "hourglass" assembly; (4) battery; (5) hydraulic unit; (6) oxygen bottle; (7) coolant radiator; (8) aft baggage door; (9) coolant radiator scoop. The detail insert at the lower right shows an exploded view of the coolant radiator assembly.

Boeing B-29

The fuselage (1) of the war-famed B-29, one of the most efficient bombers from the standpoint of speed, load-carrying ability, and range to be used in the Second World War, contains a pressurized control cabin (2, 3) and gunner's compartment aft of the bomb bay with a connecting tunnel (4). The portion in between is unpressurized.

The double bomb bays have doors of built-up construction with both inner and outer skins attached to the fuselage by four hinge arms each. The doors open and close electrically.

The armament consists of a gunner-operated cannon in the tail and remote-controlled .50-caliber gun turrets. The forward part of the fuselage is of conventional bulkhead, stringer, and stressed-skin construction. A cap of transparent plastic fits onto the nose which, together with the generous number of windows, provides an extremely wide range of visibility for pilot, copilot, and bombardier.

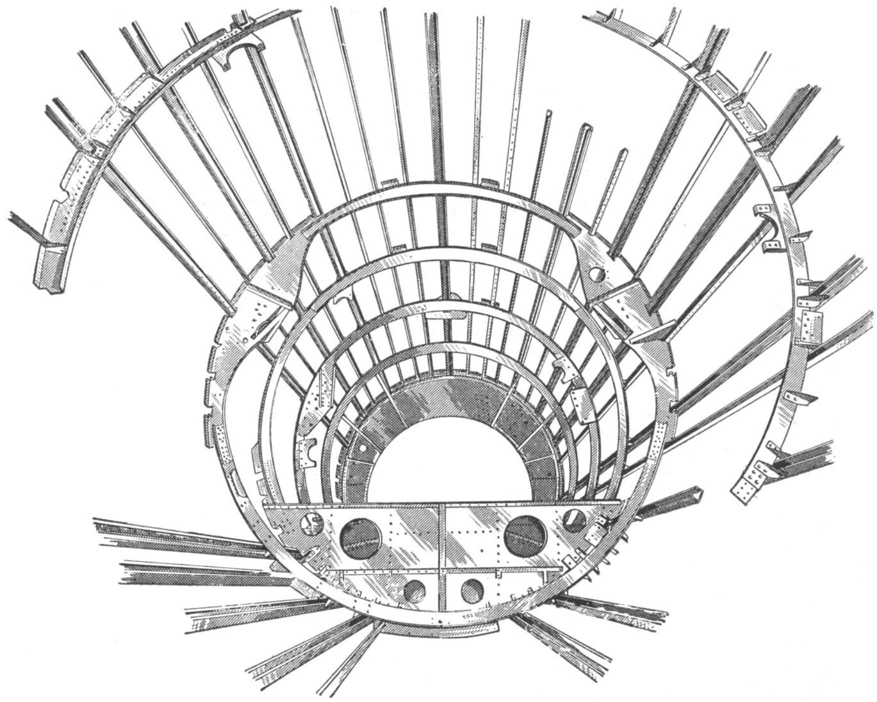


Fig. 1. Skeleton view of part of a B-29 Superfortress fuselage, showing circumferentials and stringers prior to installation of the skin. The lighter stringers are L-shaped; the heavier ones are U-shaped.

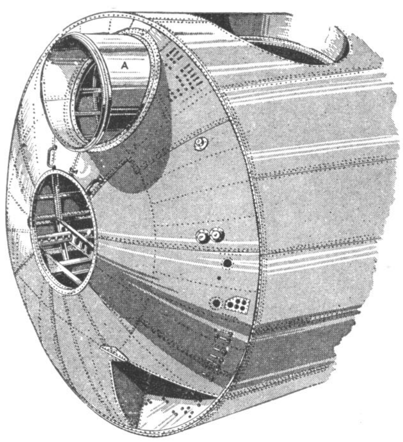


Fig. 2. View of the aft portion of the cabin control section of a Boeing B-29, showing the shape of the bulkhead between the pressurized and unpressurized sections. Note the cylindrical shape of the fuselage, an ideal section for pressurized structures. A tunnel for passage of the crew over the unpressurized section, which attaches to the left end of this section, is shown at *A*.

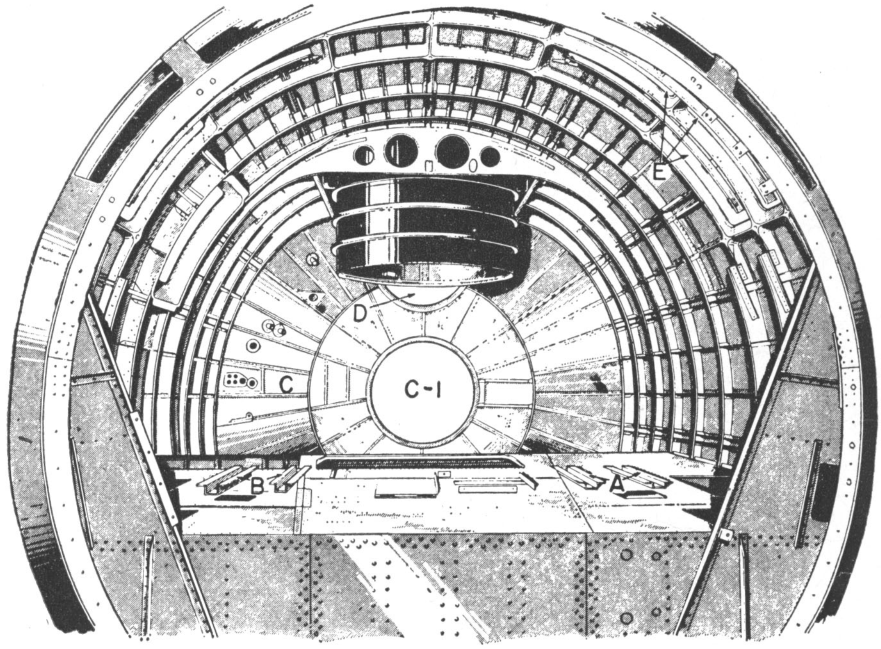


Fig. 3. An interior view, looking aft, in the cabin control section of the B-29. The foundations for the pilot's and the copilot's seats are at *A* and *B*, respectively. Concave bulkhead *C* (to which center portion *C*-1 is still to be added) separates this section from unpressurized bomb bays. The bottom part of the tunnel through which crew members may crawl from one pressurized section of the craft to another over bomb bays is shown at *D*. Some of pilot's windows can be seen at *E*.

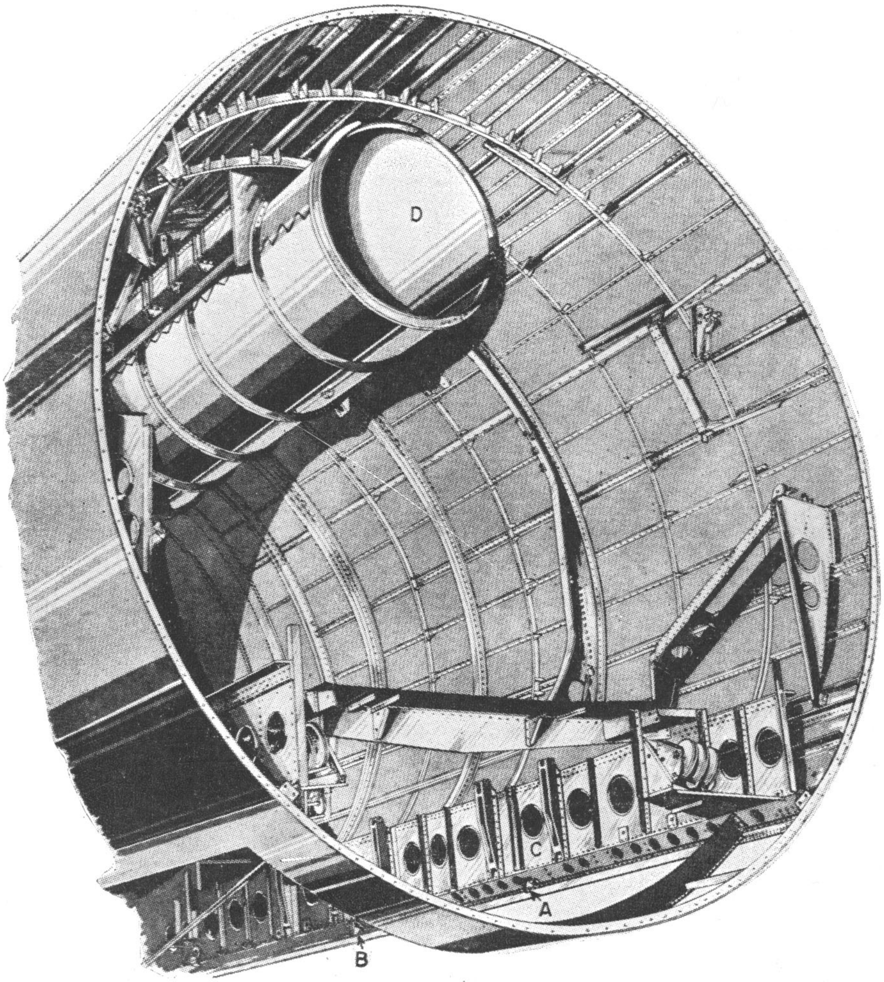


Fig. 4. Cross section of the B-29 Superfortress fuselage—9 ft in diameter at this point—at the fore end of the first of two bomb bays. Bomb-bay doors attach to hinges (two of which are shown at *A* and *B*) at the bottom of the built-up structure *C*. This portion of the craft is not pressurized, so tunnel *D* is provided for crew members to move between the pressurized control cabin and the gunners' compartment aft of the bomb bay. Note the varying sizes of frames used in this section.

Boeing B-17

Basically unchanged, the B-17 fuselage nevertheless has undergone, like the vertical fin assembly, considerable modification and modernization. To provide for the added tail-gun position, it was necessary to increase the diameter of the rear half of the fuselage. This did not, however, require a revision of the basic, original design formula.

The circular fuselage cross section was adopted because it is more efficient from the standpoint of strength–weight ratio and ease of manufacture. In the latter respect, the ability to form the skin and stiffeners in continuous forming dies was a production factor which influenced design.

An all-metal, semimonocoque structure, the fuselage (1) has a maximum cross-sectional height of 103 in. and maximum width of 90 in. The structural design (2), like that of the wing, is such that strength is well distributed, and while built around rail-section longerons in the forward half, damage to one or more of them does not necessarily cause failure to the entire structure.

The front section, including the bomb bay (5), has three rail-section longerons of extruded 24ST, two in the top and one at the bottom to carry the load and reinforce the pilots' compartment which is a cutout in the top of the basic monocoque structure. All three rail sections taper from the wing joining area toward the front, reducing from I to T sections.

The lower longeron splices into the lower chord of the bomb-bay beam on top of which is a catwalk. This truss, consisting of upper and lower chords and diagonals built up of square 24ST tubing with extruded T's and web members, furnishes support for the center bomb racks and provides body-bending continuity through the bomb bay.

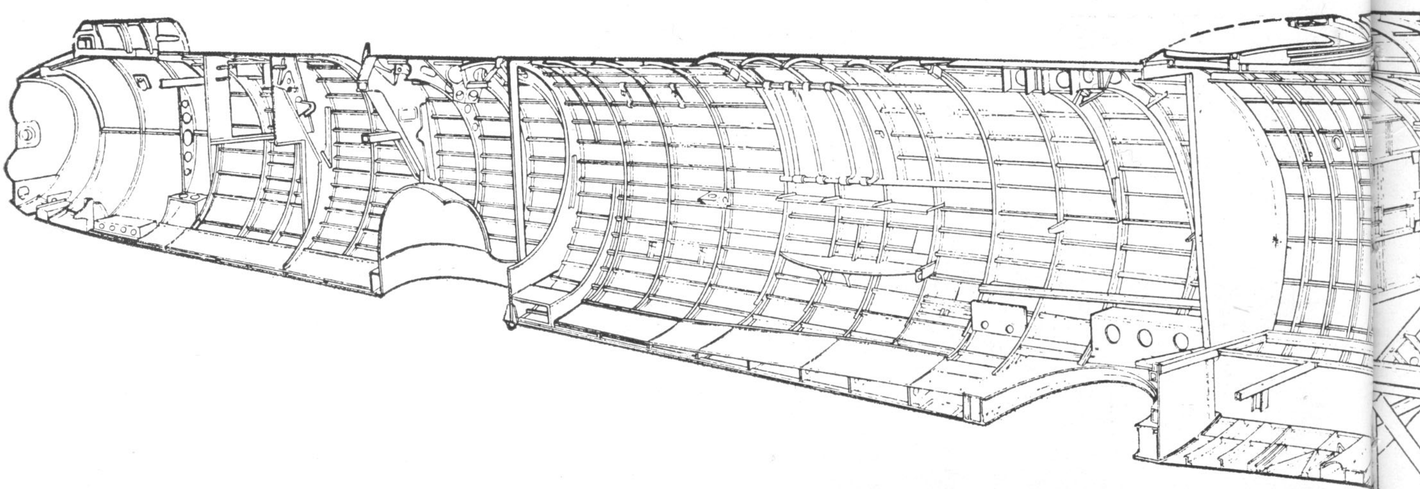


Fig. 1. Structural details of the fuselage assembly. The nose section accommodates the bombardier's equipment. The pilot's and copilot's compartment is next, above and to rear of which is an opening for the top turret. Then follows the bomb bay, showing a catwalk and its supporting truss. To the rear of the bomb bay is the radio compartment with a camera well at the bottom and an opening for a dorsal gun at the top.

The center bomb racks also serve as structural members giving column support to the lower chord of the catwalk truss or bomb-bay beam. In the bomb bay are truss-type body compression struts (3) on both sides to carry part of the load past the interrupted longeron-stiffener structure, and to aid in transmitting wing torsion to the fuselage. The side bomb racks are fastened to these compression struts.

At bulkheads 4 and 5, the ends of the bomb bay, crosswise strength is carried by four heat-treated square steel tubes, two in each end, forming continuations of the upper and lower wing spar chord loads. Square tubing members of 24ST connect the steel tubes trusswise.

The fuselage load is carried in the portion just aft of the bomb bay by four rail-section longerons which taper out aft of station 6. Additional reinforcing for the ball turret cutout (4) is provided by the lower two longerons, giving the fuselage the required strength. The upper two longerons provide reinforcing for the radio compartment gun hatch.

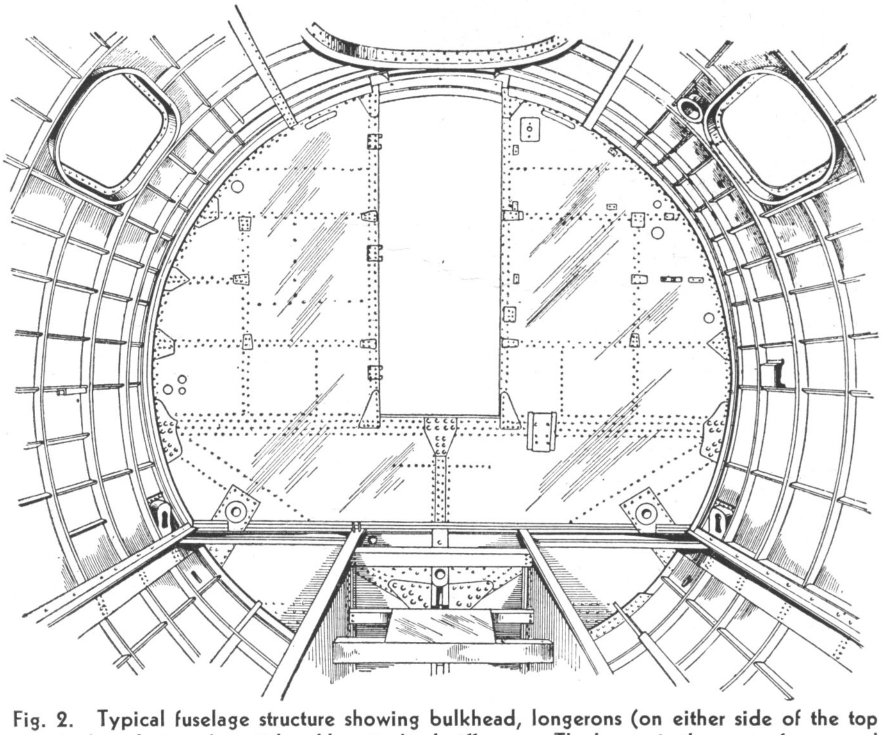
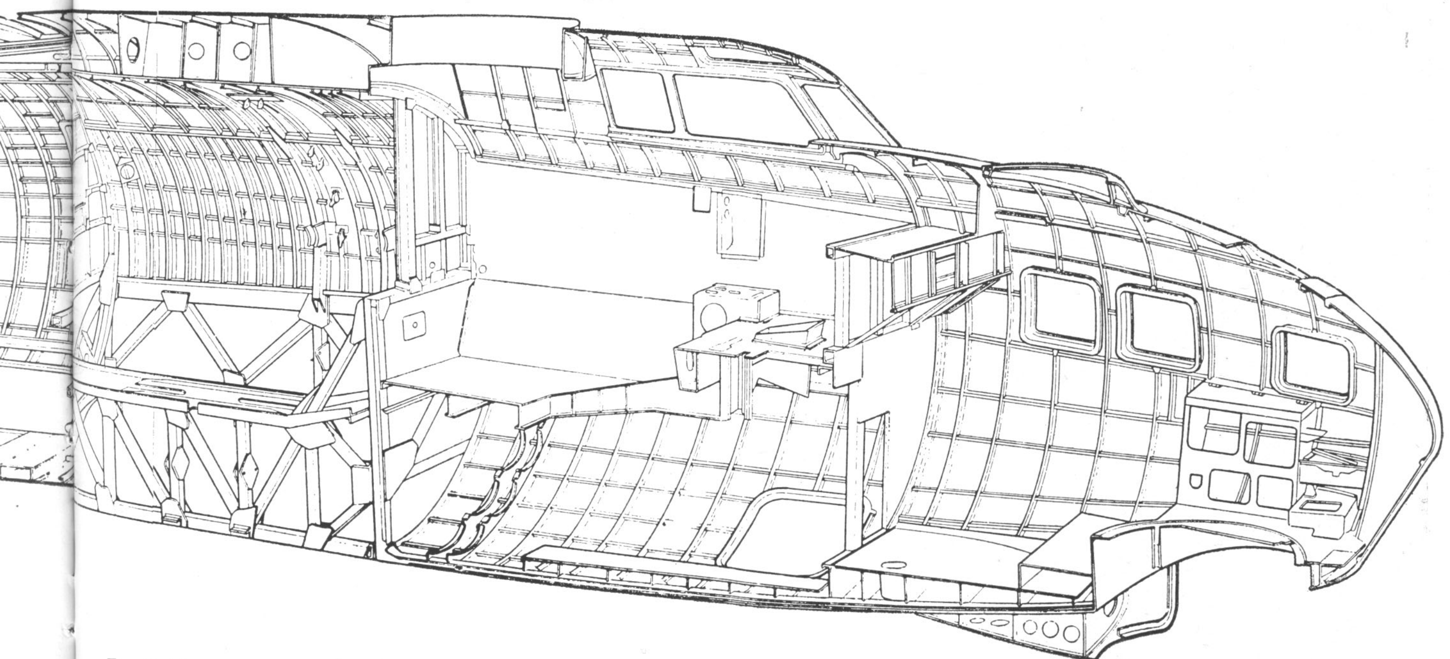


Fig. 2. Typical fuselage structure showing bulkhead, longerons (on either side of the top opening), and circumferential and longitudinal stiffeners. The beams in the center foreground are floor supports, with a camera well between.

About half of the fuselage aft portion does not have the heavy rail-section longerons, depending for its strength upon a greater concentration of lighter extruded bulb angles and heavier circumferentials. All the latter, Z type, are formed from 24ST sheet and vary in spacing from 10 in. forward of station 6 to 20 in. aft of station 6, being heavier where the spacing is wider.

Bulkheads of varying design are used for distributing concentrated loads from the wing, tail gear, and empennage to the fuselage. They vary from solid—except for the passage door—to bulkheads with slightly more than unusually wide circumferentials. All are built up from flat sheet, rolled and stamped sections, and extrusions, riveted together. In addition to imparting strength, they provide convenient supports for the control linkage and equipment.

The truss around the bomb bay serves as the anchor point of the wing



The first lower opening after the radio compartment is for the lower turret; the second is for the tail-wheel well. The raised enclosure above the tail contains the rear gunner's sighting window at the end.

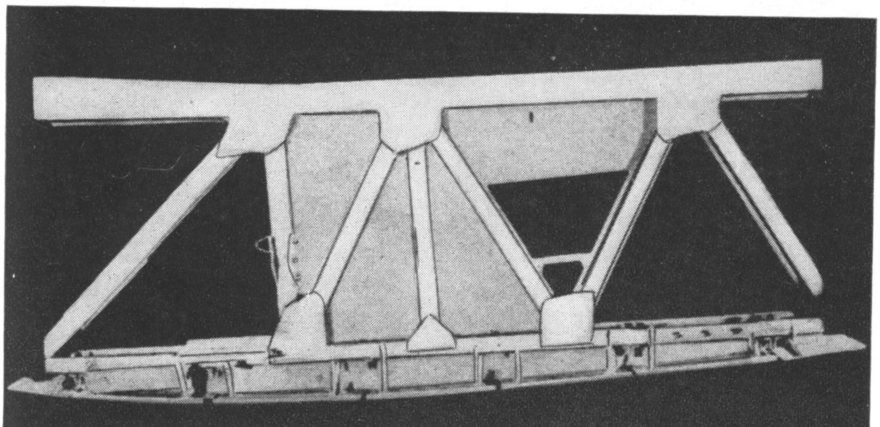


Fig. 3. A body compression strut located in the bomb bay. The doors are attached to hinge supports on the bottom member.

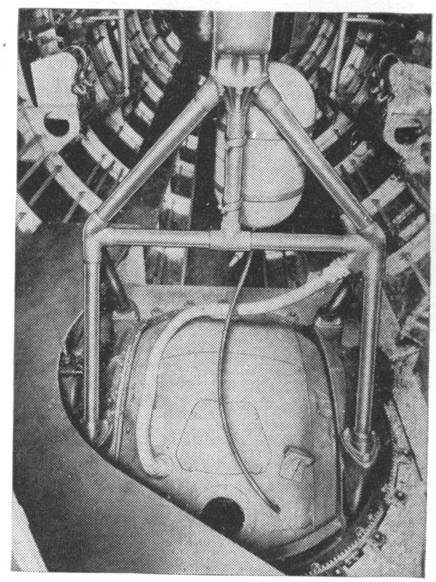


Fig. 4. Interior view showing the mounting of the bottom gun turret. Azimuth gear is seen at the lower right. Also visible are gunner's oxygen bottle and line, and turret power conduit.

terminals, which are connected to the crosswise trusses in the fore-and-aft ends of the bay, projecting outside the fuselage. A similar carry-through arrangement at bulkheads 8, 9, and 10 in the aft section supports the empennage assembly. The carry-through members are 24ST tubes and hydro-pressed sheet webs. Bulkhead 7, which has two vertical members, supports the tail-wheel structure.

The front fin spar terminals are attached to bulkhead 9, and rear fin spar terminals attach to bulkhead 10 (6). Stabilizer terminals are just outside the fuselage at stations 8 and 9 to which they attach.

Built as a separate component, the tail gunner's compartment (7) relies primarily on skin and circumferential stiffeners for its strength, having no longitudinal stiffeners.

The framework of the bomber consists of bulkheads and circumferential stiffeners tied together throughout the fuselage length by longerons and lon-

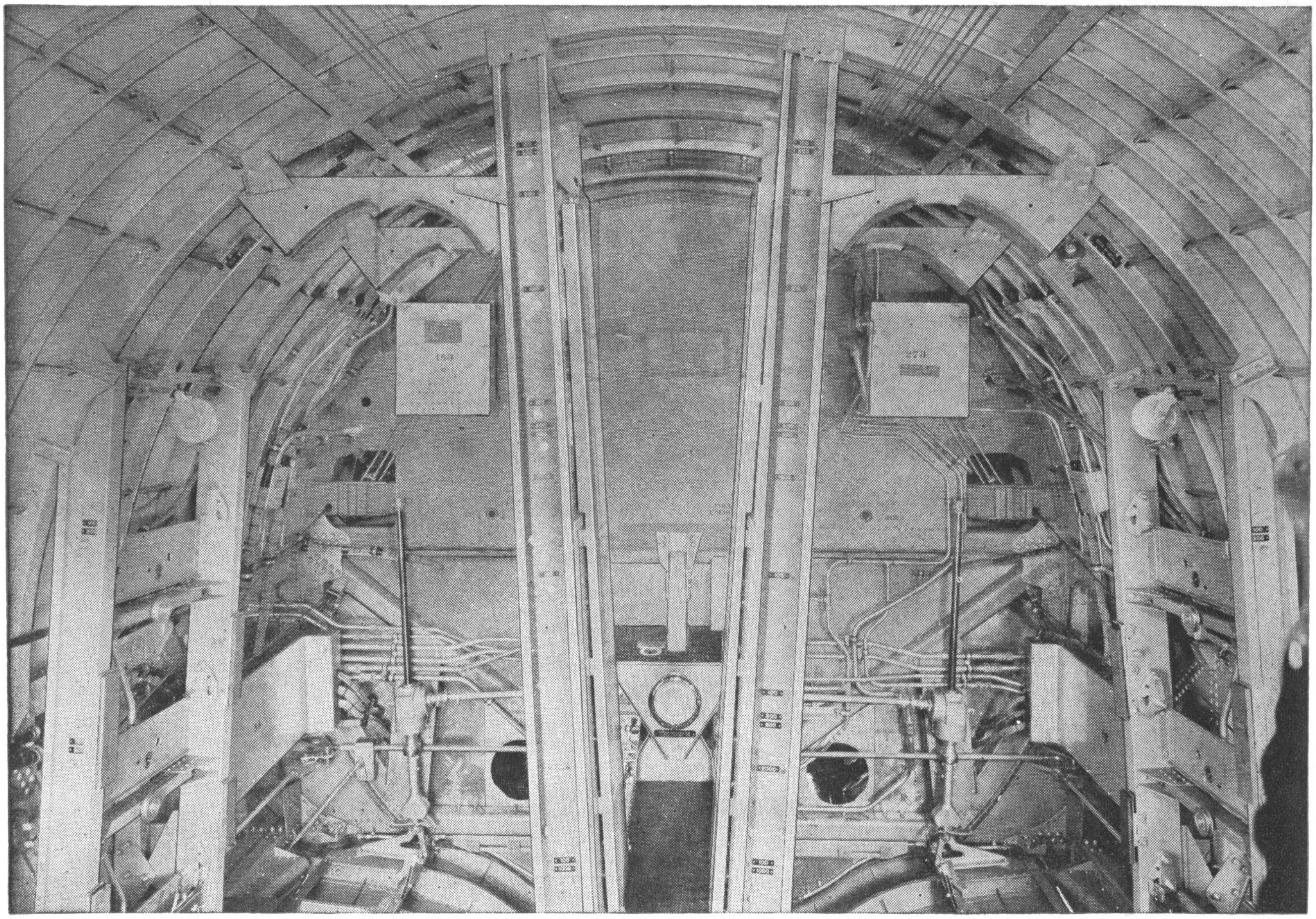


Fig. 5. Interior of the bomb bay, looking forward. Left and right of the catwalk light at the rear are gear boxes and actuating screws for the bomb-bay doors. In the center are inboard bomb racks fitted with tank cradle upper supports. Outboard racks are seen at the fuselage sides.

gitudinal stiffeners aft to station 11; front and rear spars in the wing; cross-ties of the nose, center, and tail ribs; and ribs and formers in the tail surfaces. A skin of 24ST alclad is laid over this framework and fastened with aluminum alloy rivets. The thickness of the skin varies with the locality and depends upon the amount of load carried.

Supports for the pilots' cockpit are large built-up beams under the floor, sloping aft to connect with the pilots' cabin floor structure supporting the top turret immediately behind the pilot and copilot seats, and anchoring to bulkhead 4 below the cockpit.

There are four means of emergency exit and entrance: a releasable hinged door in the forward fuselage portion; a releasable hinged door near the tail gunner's position, on the starboard side; a releasable hinged door forward of bulkhead 7; also one on the starboard side. All except the bomb-bay doors are operative from either inside or outside. In addition, the pilot's and copilot's windows and radio compartment hatch may be used in an emergency.

The cockpit, reached through a doorway in the bulkhead between it and the bomb bay, has pilot seats adjustable vertically and fore and aft which accommodate seat or back-type parachutes. The front window panels are fixed and leakproof; sliding-type side panels are of shatterproof, dehydrated glass, $\frac{1}{4}$ in. thick. The fixed side panels are $\frac{3}{16}$-in. transparent plastic.

The engine nacelles are typical monocoque structures with 24ST extruded longerons and several formed longitudinals located between the evenly spaced longerons. Longitudinal members are tied together with rolled sheet Z-section circumferentials, spaced about 10 in. apart. The skin is 24ST except around the exhaust stacks, where stainless steel is used. The fire wall also is of stainless steel.

Engine mounts are standard ring type of normalized X4130 steel tubing, arc-welded with X4130 steel forgings at the four fire-wall connections. All mounts are interchangeable.

The spacing between the fuselage fairing and wings is about 10 in. to provide for the wing joint, and is covered by hydro-pressed 24ST alclad sheet fairing held in place by means of machine screws and nut plates. The horizontal stabilizer, spaced with a 15-in. gap between it and the fuselage, also is covered with fairing.

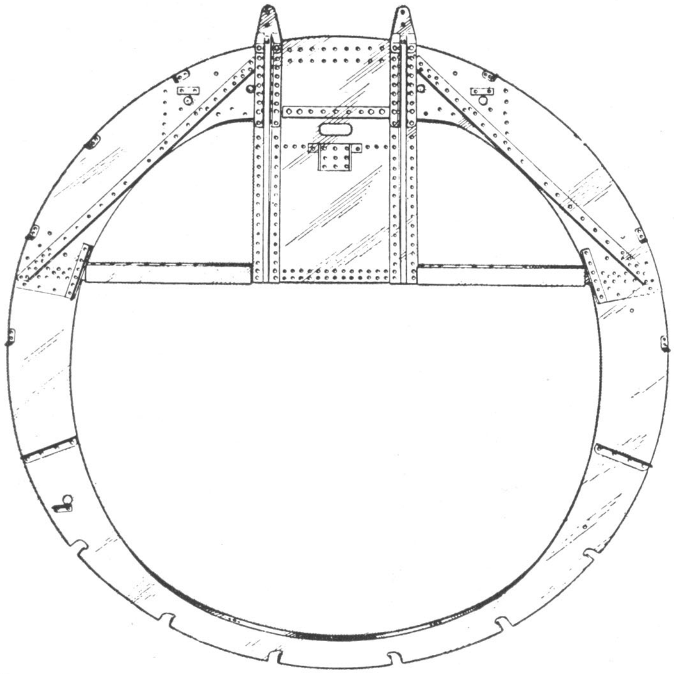


Fig. 6. Rear view of bulkhead 10, located aft of the tail wheel, under the vertical fin rear spar. Terminals for spar attachment are at the top.

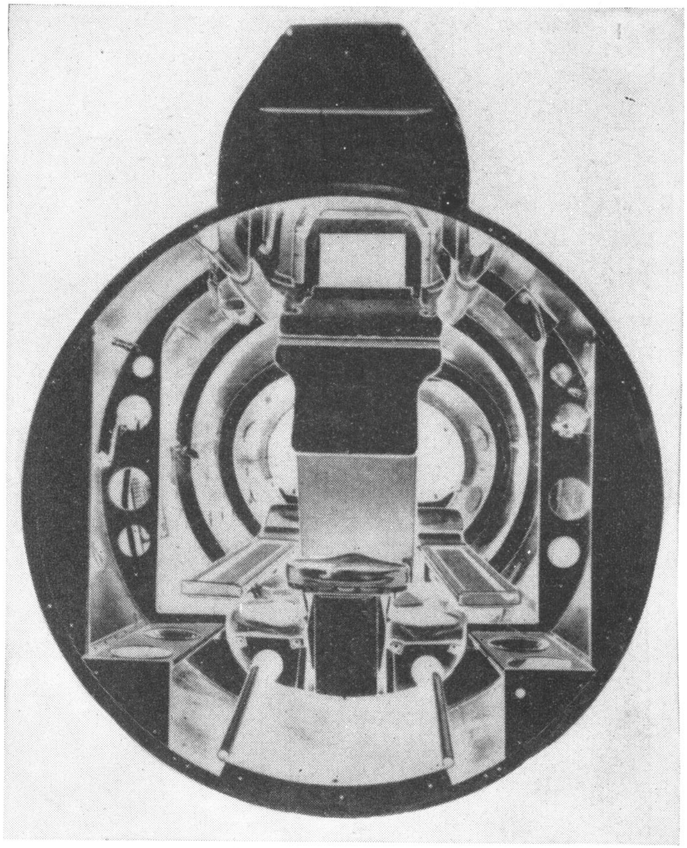


Fig. 7. Interior view of the tail gun emplacement aft of bulkhead 11. In the center is an adjustable seat behind armor plate with the upper portion covered with rubber shock pad. A bulletproof window is at the end of the top enclosure. A cartridge chute is seen at either side of the seat.

Consolidated Vultee B-24

The B-24 fuselage, 66 ft 4 in. in length and with a maximum height and width of 10 ft 5 in. and 7 ft 5 in., respectively, is a semimonocoque shell consisting of smooth skin reinforced with Z-type 24ST alclad rolled stiffeners or stringers, and transverse bulkheads and belt frames (1). The longitudinal stiffeners generally are spaced at about 6-in. intervals, with greater concentrations where required for added strength. Longerons are used only to carry loads around openings at the bomb bays, access doors, and other points where the skin-stringer combination is broken.

To maintain fuselage shape, belt frames are .040 24ST alclad lipped channel, notched to pass over stringers and spaced about 1½ ft apart.

In the bomb bays, where belt frames and longitudinal stringers are interrupted in the lower half of the fuselage, vertical stiffeners are spaced about 7 in. apart to avoid passing stringers around or over bomb-bay door tracks. The side longerons are channel shape, 5 in. wide and 2 in. deep at their widest part in the bays, tapering out 6 to 8 ft both ways.

Because strength is dispersed rather than concentrated in a few critical members, skin-stringer–bulkhead-belt frame structural design was used, a distinct advantage in any assembly subject to combat damage.

By building the fuselage around the wing, juncture weight was saved through elimination of heavy fittings and bolts at the attachment points, and fuselage torsional stiffness was improved. This method joins the fuselage and wing by means of a continuous riveted and bolted attachment around the periphery of the box structure of the wing formed by the upper and lower surfaces and the front and rear spars (2).

Bulkheads are at the ends of the bomb bays, connected longitudinally to a partial bulkhead in the center between the two bays by a beam which also forms the catwalk. The aft-end bulkhead is a plate girder type built up of rolled sections and flat sheet. The upper part of the front bulkhead is a truss; the lower portion is flat sheet. The partial bulkhead between the two bays extends upward only to the wing to provide lateral support to the catwalk.

The catwalk through the bomb bays serves as a longeron and provides for transverse and longitudinal loads from the bomb racks. It consists of two U-shaped channels forming the sides, a corrugated alclad top serving for the walk, and a smooth alclad bottom forming part of the outside skin of the fuselage. Pressed sheet diaphragms, spaced about 2 ft apart, maintain the catwalk cross section. The walk ends aft at a curved box beam which trans-

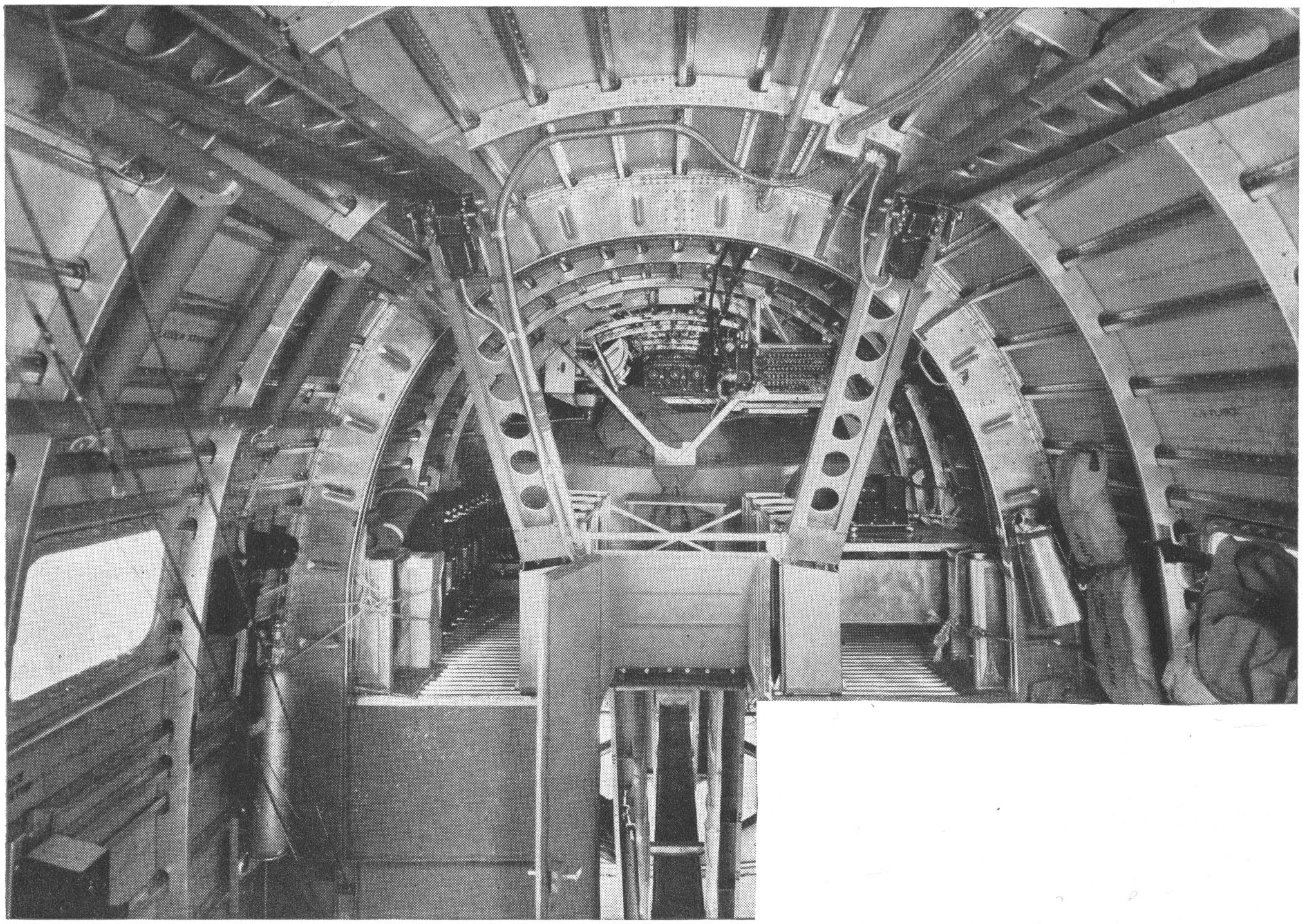


Fig. 1. Interior view of the fuselage showing the arrangement of longitudinal stiffeners and belt frames. Also seen are ammunition tracks, and bomb-bay catwalk and racks are visible through the door in the bottom center.

mits loads to two longerons around the ball turret opening. These taper out 4 ft beyond the turret opening. Forward, the walk tapers out ahead of the forward bomb bay. Around the nose-wheel well, loads are passed through auxiliary longerons.

The nose-wheel gear attaches at four points. Two upper attachments are to the floor truss of the radio operator's compartment, the truss passing loads to the fuselage sides. The two lower attachments are to the main bulkhead of the cockpit. A plate girder, built up of rolled sections and flat sheet, transmits loads to the fuselage shell.

The rear bomb-rack vertical supports are welded-steel tube trusses, in turn welded to gusset plates which are riveted to the rear spar of the wing. The forward racks tie to the lower surface of the wing by bolted fittings which pass loads to the wing internal structure. Bomb loads, because of this means of supporting the racks, are actually carried by the wing, rather than to the wing by means of the fuselage. For load purposes, the wing attaches to the fuselage through bolting and riveting of channel-type bulkheads to the front and rear spars of the wing.

Bomb-bay doors are flexible and made up of corrugated section, 24ST alclad, spot-welded and riveted to an outer alclad skin. To open, they slide up on the outside of the fuselage by means of rollers attached to the ends of the corrugations and running in curved tracks.

The bombardier's compartment is merely a continuation of the fuselage nose section. Of standard flat-sheet monocoque construction, it is supported by stringers and three bulkheads built of formed U channels of alclad and 24ST sheet. Forward of the bombardier's position, the fuselage supports a tublike structure in which the forward turret is mounted. The supporting structure is carried on two short and heavy deep beams of 24ST alclad, bolted to the foremost fuselage station bulkhead by heavy aluminum alloy forgings.

The pilots' enclosure, which is faired into the main portion of the fuselage, is approximately midway between the fuselage front and the leading edge of the wing.

Immediately aft of the cockpit enclosure, the flight deck has a floor slightly lower than the pilots' floor. The deck carries drag loads from the main landing gear back to the wing and also supports the radio equipment and operator.

Emergency exits are provided in the top of the fuselage above the bombardier and pilot positions, and in the bottom of the fuselage aft of the waist gun position for the tail and waist gunners. The bombardier also may leave by way of the nose wheel door, while the pilots and upper gunner may leave through the forward bomb bay. The waist and tail gunners can also use the waist-gun windows.

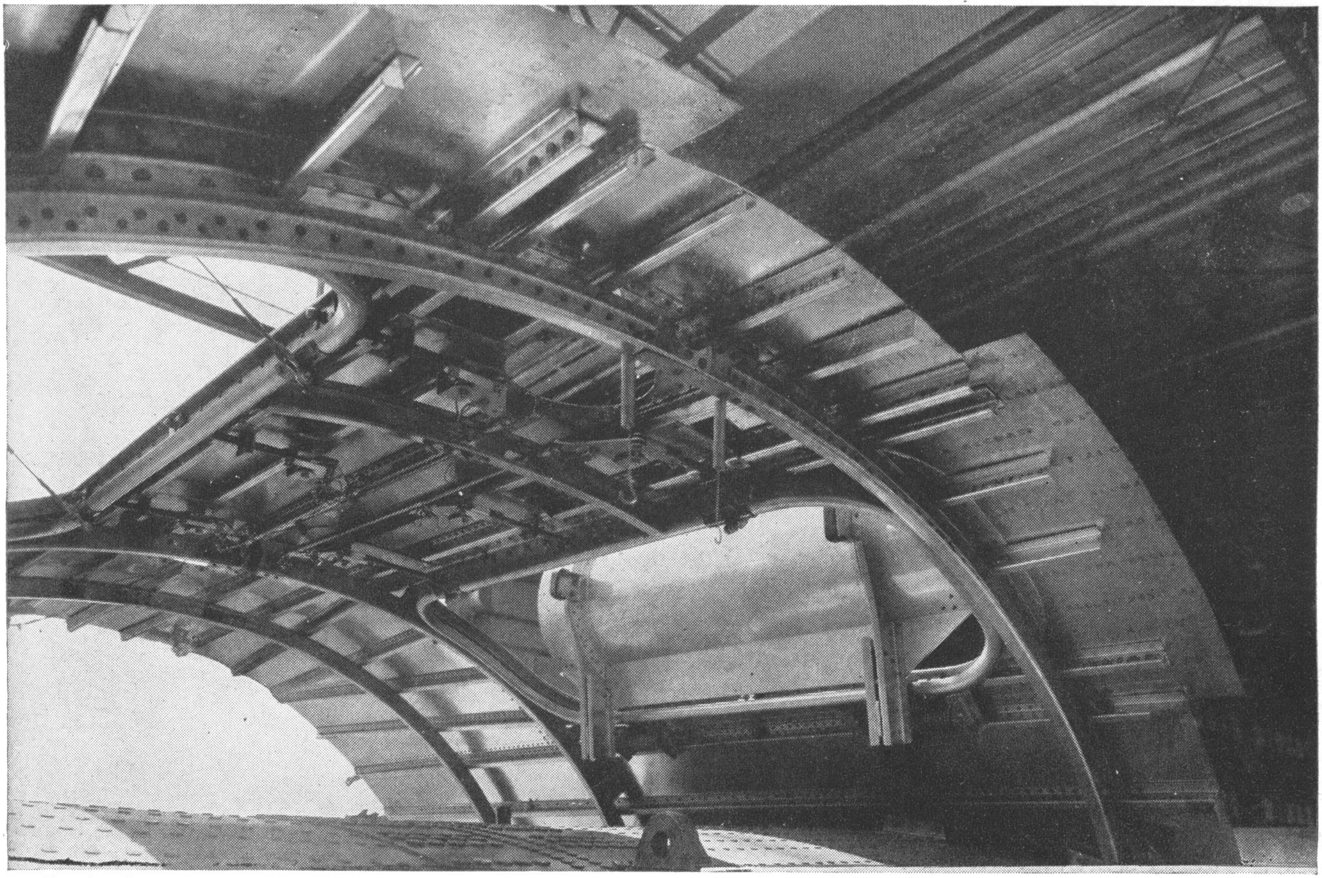


Fig. 2. Structural details of the fuselage interior above the fuselage-to-wing splice. A life-raft cradle is seen at the lower center.

Avro Lancaster

Britain's principal heavy bomber, noted for the great bomb loads it dropped in area attacks on German industrial centers, was the Avro Lancaster, a four-engined, twin-tail fin type which was a development from the earlier Manchester.

British bomb bays which ran to length rather than to depth as in most contemporary American types are illustrated by the over-all view of the Lancaster bomb bay (1). The floor construction over the bomb bay includes intercostals, cross members, top and lower skins, and bomb carrier housings (2).

Because the British bombers operated mainly in night offensives against the enemy, the armament consisted of .30-caliber machine guns in turrets. In night attacks, intercepting fighters were forced to move in far closer to their quarry than was necessary in daylight when the bombers could be seen more plainly. The light .30's, especially when mounted in clusters of four

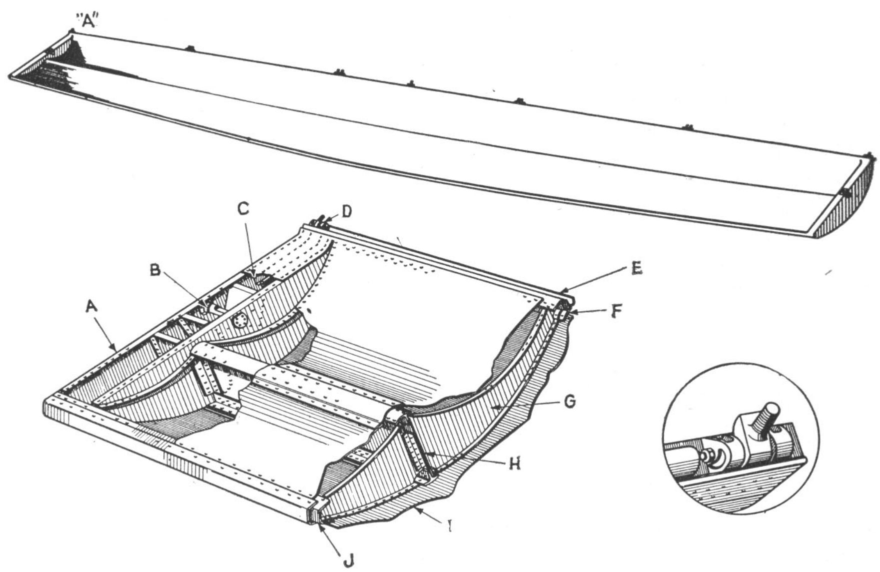


Fig. 1. An over-all view of a Lancaster bomb-bay door is shown at the top, with the detail sketch revealing the construction shown below. End rib is at *A*; opening and closing jack attachment at *B*; stiffener at *C*; and hinge *D* is shown enlarged in the circle at the lower right. Sealing strip is at *E*; hinge channel at *F*; intermediate rib at *G*; spar at *H*; bomb-door outer skin at *I*; edge channel at *J*.

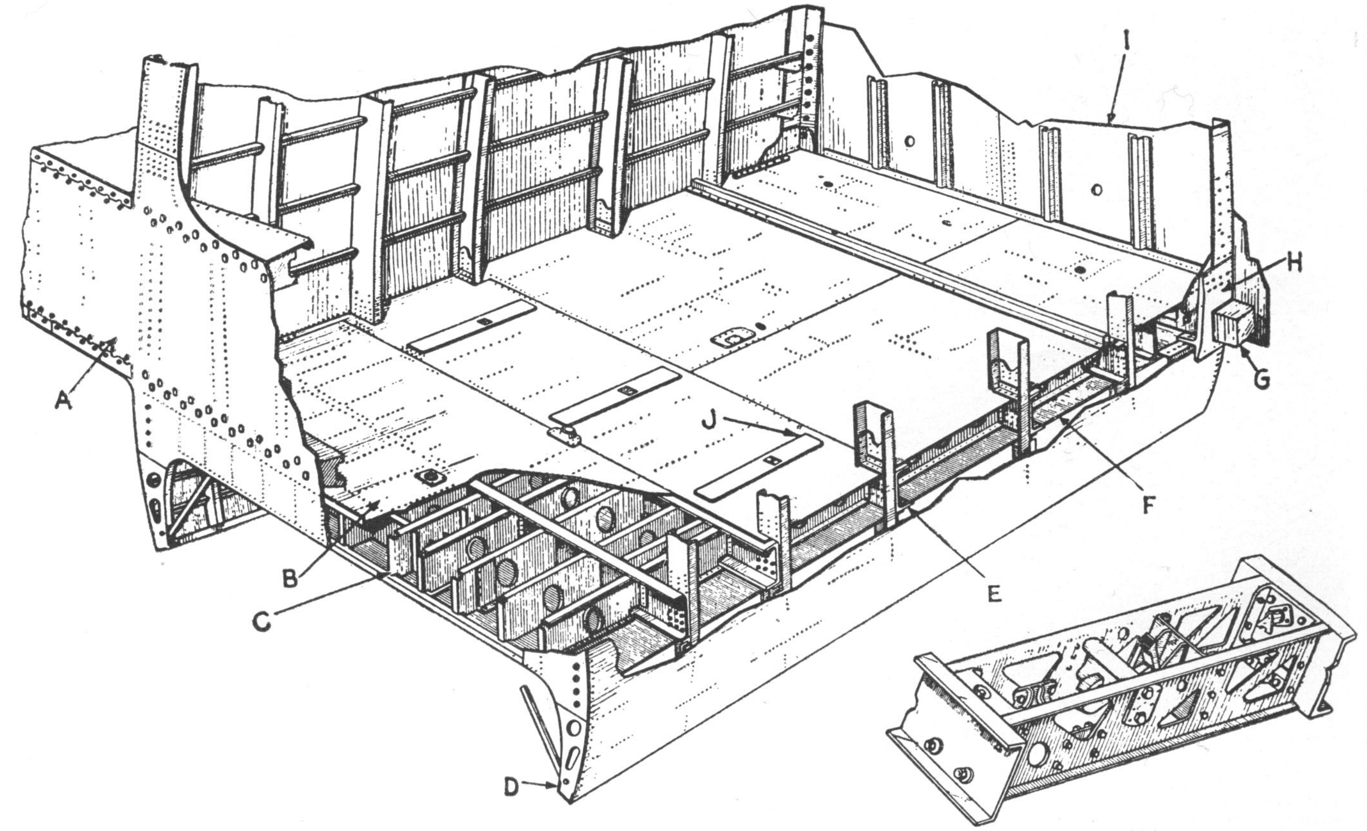


Fig. 2. Avro Lancaster floor construction over the bomb bay with front spar at *A*; top skin of floor at *B*; typical intercostal at *C*; bomb-bay door hinge channel at *D*. A typical floor cross member is shown at *E* and lower skin floor at *F*. The rear spar bottom boom is at *G*; longeron at *H*; rear spar at *I*. The detail sketch at the lower right shows the bomb carrier housing below point *J*.

in the tail and upper fuselage turrets, were sufficient to discourage close-in attacks.

The Lancaster carried a front gun turret mounting in the nose, mid-upper fuselage turret (3), mid-lower fuselage turret, and a tail "stinger."

The cockpit canopy construction included a steel tube frame forming the top structure, and spruce contour frames joined to the steel tube structure. Sliding window panels were provided at the pilot's positions. In addition, a direct-vision window was set in the top forward part of the windshield, opening inward on a hinge.

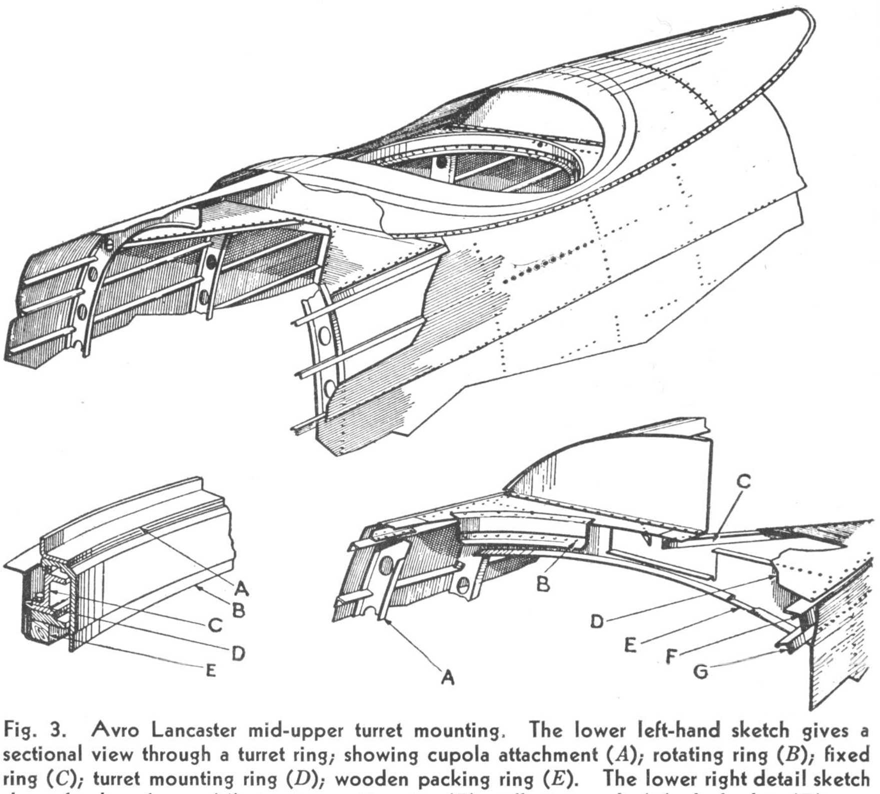


Fig. 3. Avro Lancaster mid-upper turret mounting. The lower left-hand sketch gives a sectional view through a turret ring; showing cupola attachment (*A*); rotating ring (*B*); fixed ring (*C*); turret mounting ring (*D*); wooden packing ring (*E*). The lower right detail sketch shows fuselage former (*A*); turret mounting ring (*B*); stiffening angle (*C*); deck plate (*D*); rear cross member (*E*); longeron (*F*); stringer (*G*).

Lockheed Constellation 049 and 149

The Constellation fuselage is of aluminum alloy, semimonocoque construction, circular in cross section except for the windshield area and the extreme aft portion to which the tail assembly is attached.

The over-all length from station 110.2 to station 1189.4 is 89 ft 11 in., and the maximum diameter is 139.4 in.

The fuselage construction and sealing are such that a pressure differential of 4.1 psi can be maintained during high-altitude flight. The entire area from the forward pressure bulkhead (station 122.7) to the aft pressure bulkhead (station 1037) is built as a pressure tank in which skin joints are sealed with sealing compound.

The pressurized portion of the fuselage under the cabin floor is used for cargo compartments. The forward compartment extends aft from the rear wall of the nose-wheel well to the front beam of the wing. The aft compartment extends from the rear beam to a point just aft of the main cabin door. There is no cargo space in the fuselage (2) between the main wing beams.

The floor structure between stations 407 and 527 just forward of the front wing beam (1) consists of longitudinal and horizontal channel members varying in gauge.

The bulkhead (3) containing the door leading to the cockpit is formed of 24ST alclad channel members, doublers, angles, webs, and Z sections, in addition to SAE X4130 steel and corrosion-resistant steel material. The X4130 steel is heat-treat normalized to 90,000 psi, except for a vertical channel member which is heat-treated 125,000 to 145,000 psi.

A crew door is located just aft of the cockpit on the right side (4). The casing of the door is .064-gauge 24ST aluminum while the threshold is of .025, 302-1A corrosion-resistant steel (AMS-5515).

The fuselage skin is 24ST alclad and is provided with stiffeners of varying gauge and materials.

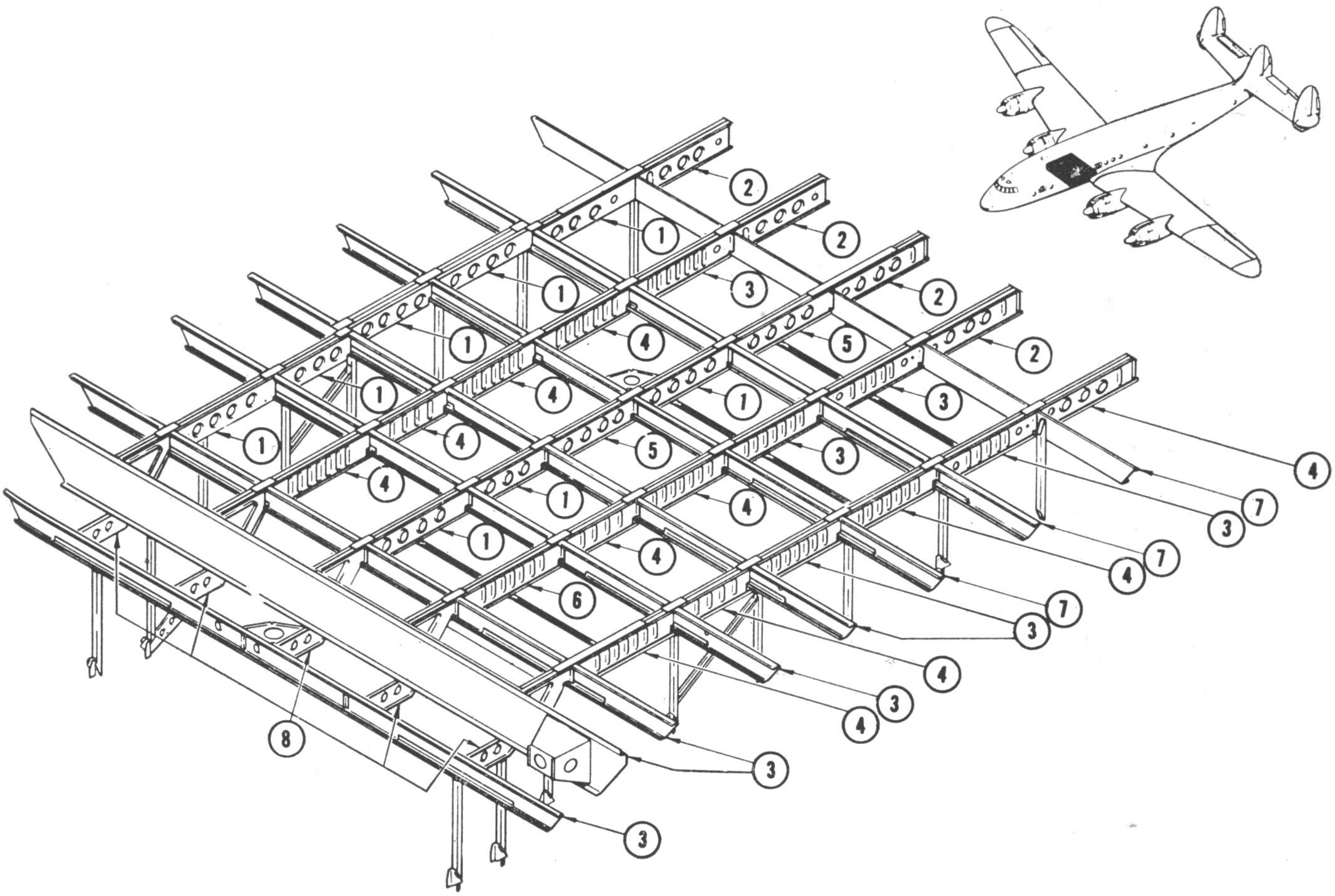


Fig. 1. The floor support structure at stations 407 to 527 forward of the front beam of the wing is composed of the following parts, all of which are 24ST alclad: (1) channel member, .025 gauge; (2) channel, .032; (3) support, .032; (4), (5), (6), and (7), .032, .025, .040, and .051 gauge, respectively; (8) support, .032 gauge. The vertical supports are LS3249.

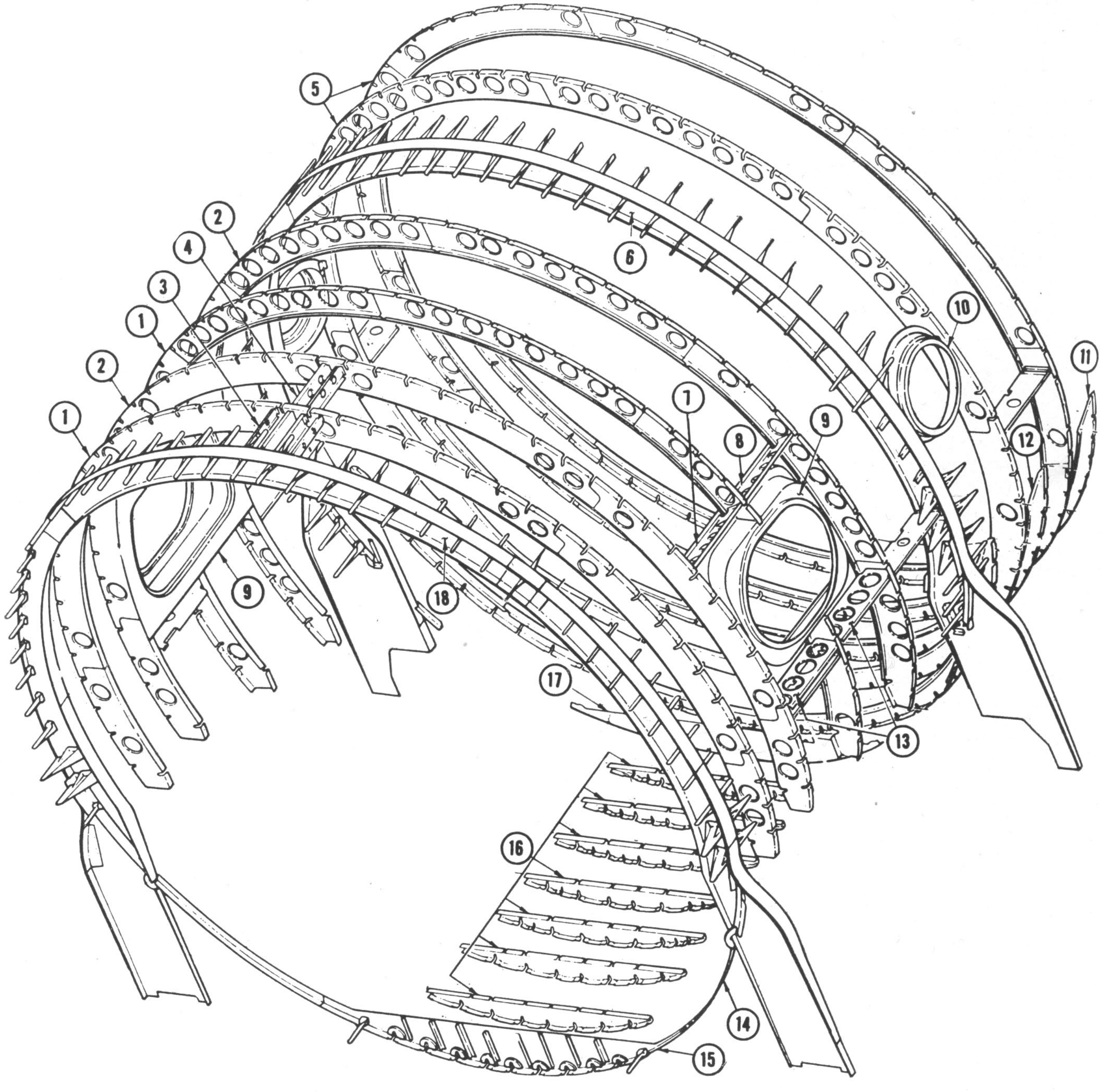


Fig. 2. The structure of the fuselage between the main wing beams (stations 528 to 658) consists of the following: (1) upper and lower L/R segments, .051 gauge (top L/R segment, .032); (2) upper and lower L/R segments, .064 (top L/R segment, .032); (3) outboard and inboard channel members, .051 and .064, respectively; (4) L/R channel, .040; (5) bottom L/R segment, .064; lower L/R segment, .051; upper L/R segment, .040; top L/R segment, .040; (6) forward-and-aft channel member, .102; forward-and-aft stiffener, LS3292; aft lower angle, LS200; (7) angle, .040; (8) angle .040; (9) emergency exit frame; (10) ring, .032; (11) bottom and lower L/R segments, .064; (12) bottom and lower L/R segments, .064 and .051, respectively; (13) channel, .040; (14) angle, LS3253; (15) bulkhead .064; angles, LS3203; (16) bulkhead, .064; (17) bulkhead, .081; angles, LS3203; (18) forward-and-aft channels, .081 forward-and-aft stiffeners, LS3292; lower inboard plate, .156 SAE X4130 steel; top inboard plate, .078 SAE X4130 steel; outboard plate, .156 SAE X4130 steel; and top outboard plate, .109 SAE X4130 steel. All SAE X4130 is heat-treated 125,000 to 145,000 psi. Other material is 24ST alclad.

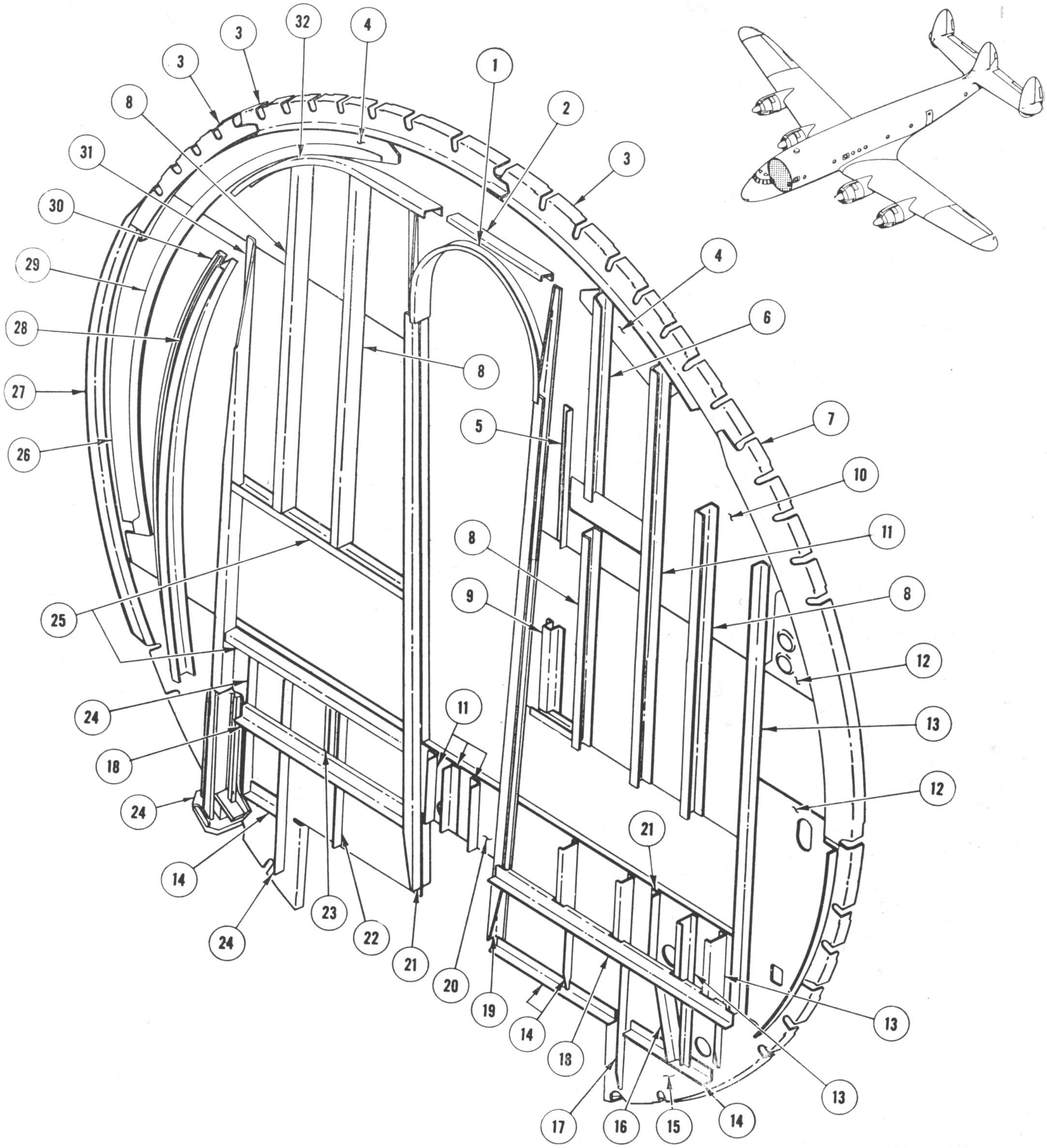


Fig. 3. Front face of the bulkhead, station 160, in the Constellation nose section. Except as otherwise noted, the material used is 24ST alclad. The parts and gauges include: (1) and (2) channel sections of .032 and .051, respectively; (3) upper left-hand segment, .064; (4) doubler, .064; (5) angle, LS220; (6) channel section, .072; (7) lower left-hand segment, .051; (8) channel, LS264; (9) bracket, .025; (10) upper web, .051; (11) channel, .081; (12) doubler, .081; (13) angle, LS3224; (14) outboard angle, LS3229; (15) lower left-hand web, .064; (16) angle, LS118-.040; (17) channel, .064; (18) Z section, .040; (19) left-hand door channel member, LS3484; (20) doubler, .062 SAE X4130 steel; (21) right-hand door channel LS3484; (22) angle, LS3567; (23) Z section, .064; (24) angle, LS3246; (25) channel, .032; (26) L/R web, .064; (27) "T", LS3431; (28) channel, .025; (29) plate, .025, 302$\frac{1}{2}$ H corrosion resistant steel (AMS 5518); (30) track, .035, 302-1A corrosion-resistant steel; (31) channel, .156 SAE X4130 steel heat-treated 125,000 to 145,000 psi.; (32) channel, .051.

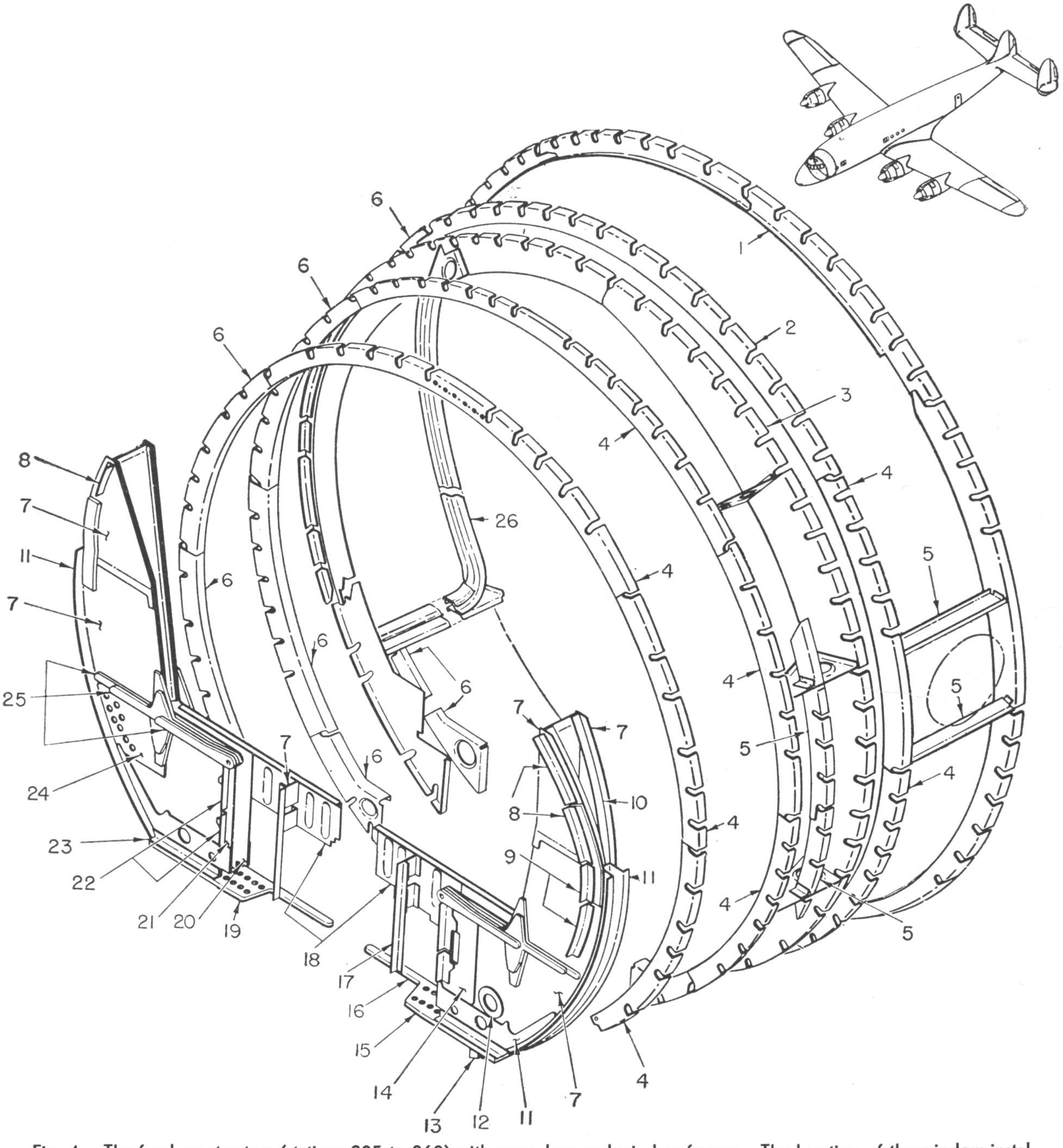


Fig. 4. The fuselage structure (stations 205 to 260) with crew door and window frames. The location of the window installations may vary. The gauges of parts (materials is 24ST aluminum except as otherwise noted) are as follows: (1) bulkhead; (2) segment, .064; (3) segments; (4) segment, .051; (5) support, .032; (6) segment, .064; (7) channels, .040; (8) angle, LS106-.032; (9) angle, .032; (10) plates, .081; (11) hat section, .072; (12) flanges, .025; (13) web, .081; (14) doublers, .040; (15) plate, .375; (16) filler, .040; (17) angle, LS109-.040; (18) web, .032; (19) plate, .375; (20) web, .072; (21) doubler, .040; (22) angle, .040; (23) angle, LS3200; (24) doublers, .064; (25) straps, .187; and crew-door casing, .064. The threshold is .025, 302-LA corrosion-resistant steel (AMS 5515), and angle, .064.

Douglas C-54

The C-54 which won fame as a military transport in the Air Transport Command and the Naval Air Transport Service has an aluminum alloy semimonocoque fuselage composed of three main sections: nose, center, and tail sections. The three sections are bolted together at butt joints through jig-drilled holes.

The fuselage is constructed of longitudinal floor beams and stiffeners, transverse frames and bulkheads, floor panels, and flush-riveted, stressed skin.

The fuselage nose section (1) houses the nose landing gear and flight compartment. The center section, containing the radio operator's and navigator's compartment and crew's quarters (3), is permanently joined to the center wing section (2, 5). A bulkhead separates the main cabin from the flight compartment, and floor panels, provided with access doors, divide the fuselage into two sections, upper and lower (4).

With exception of removable floor panels forward of the pilots' positions, all the floors are of stressed-aluminum alloy and are not readily removable. The floors incorporate doors, which provide access to the lower sections of the plane.

The tail section is bolted to the center section and terminates in a bulkhead to which the tail cone is attached. The bolt-attached cone is easily removable and contains the two tail navigation lights.

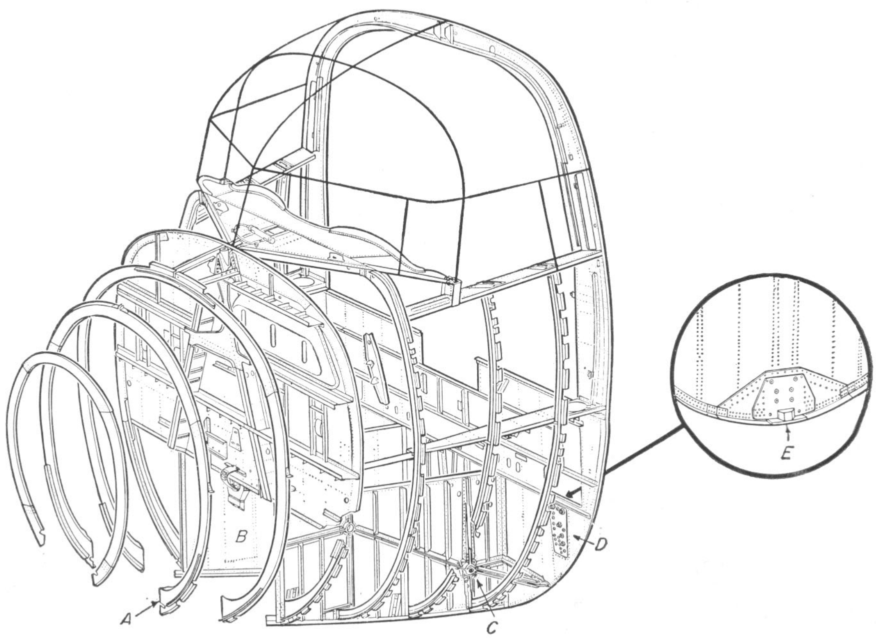


Fig. 1. Demountable nose section of the Douglas C-54, with skin and longerons removed to show the cutout in the frames for the nose wheel well (*A*) and nose wheel flight brake (*B*) employed to prevent the wheel from spinning in flight. The longitudinal beam and fittings for the nose wheel assembly are at (*C*), the line disconnect manifold is at (*D*) and in the circled sketch alongside is a close-up view (*E*) of the forward fuselage jack fitting.

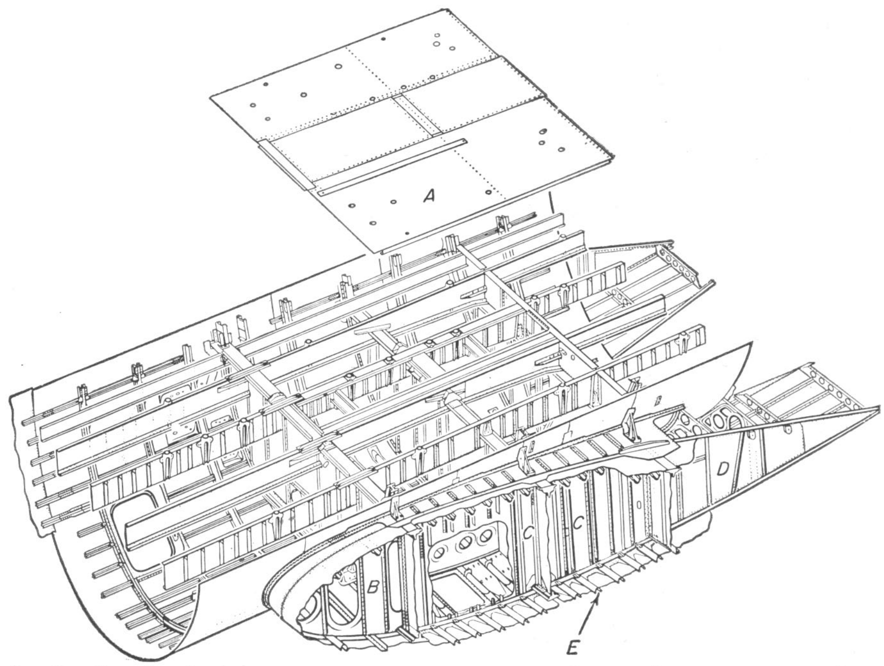


Fig. 2. Douglas C-54 center-wing section cutaway view showing the construction and installation of floor beams and a typical floor section (*A*). Also cut away is a wing to show the nose, rib (*B*), 'tween-spars (*C*), and trailing edge (*D*), together with typical hat-shaped spanwise stringers (*E*).

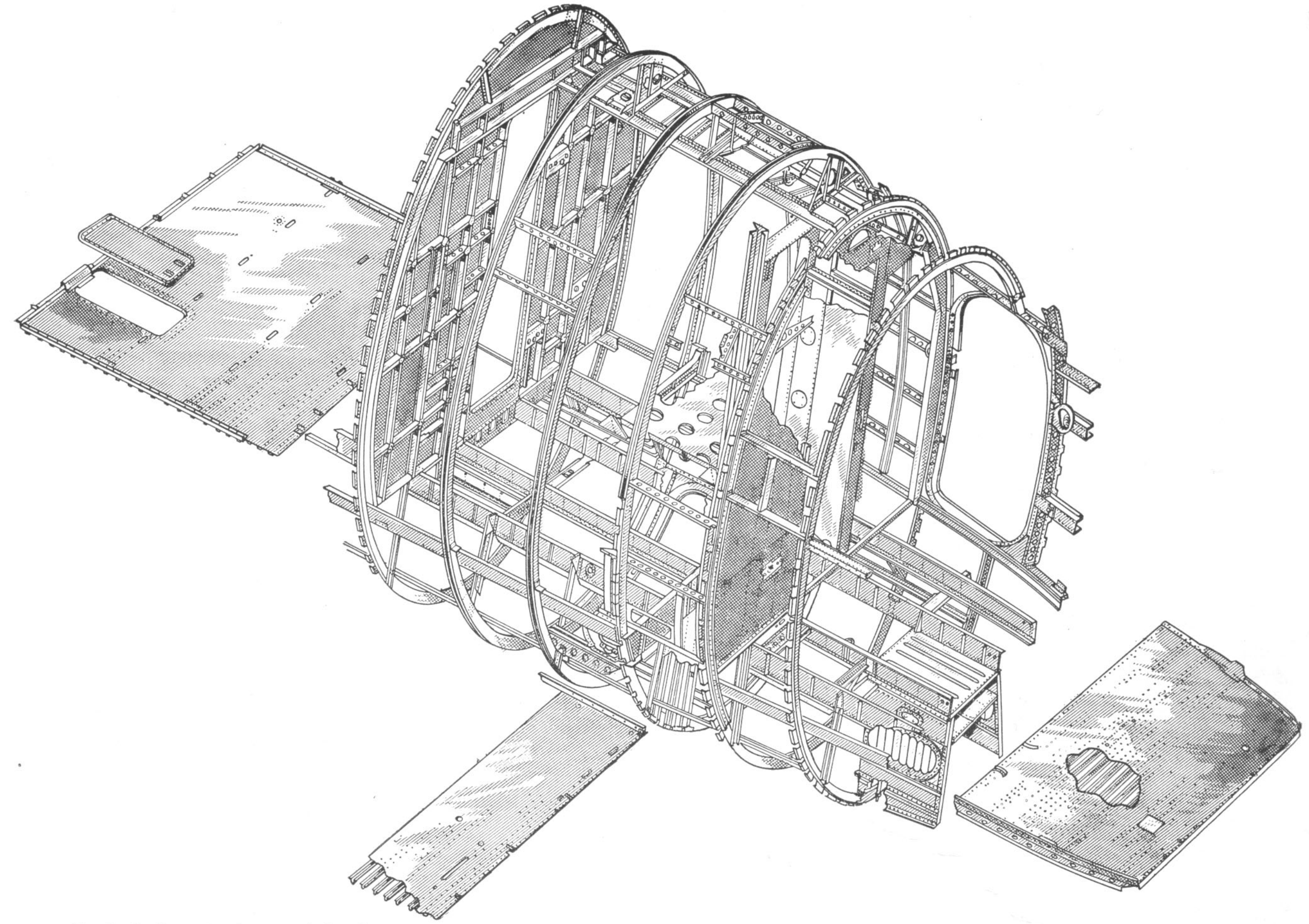


Fig. 3. Exploded view of part of the C-54 fuselage, showing the construction around the navigator's and radio operator's compartment (right) and crew's quarters (left) between bulkheads. The floor sections of each compartment have been "pulled out" to show the construction and location of floor beams.

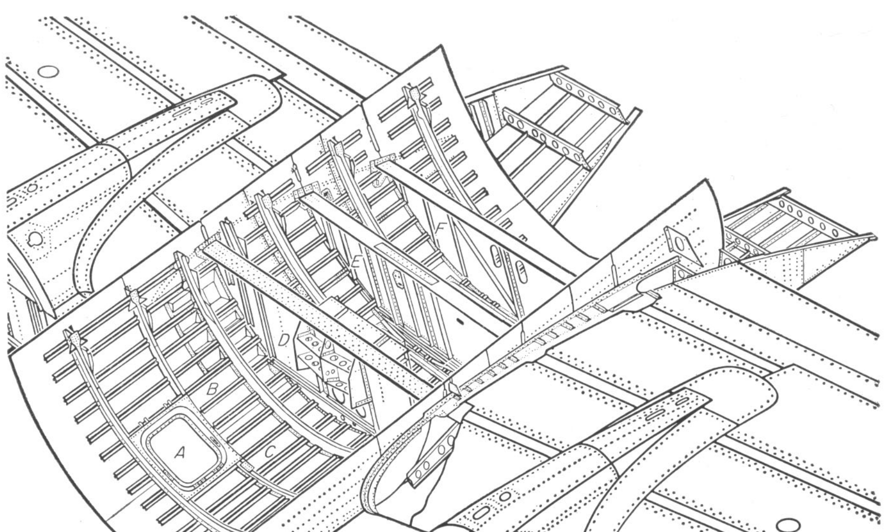


Fig. 4. Cutaway view of the lower section of the C-54 fuselage, showing belly compartment access door (*A*); typical formers (*B*); stringers (*C*), and spars (*D*), (*E*), and (*F*) extending through the fuselage.

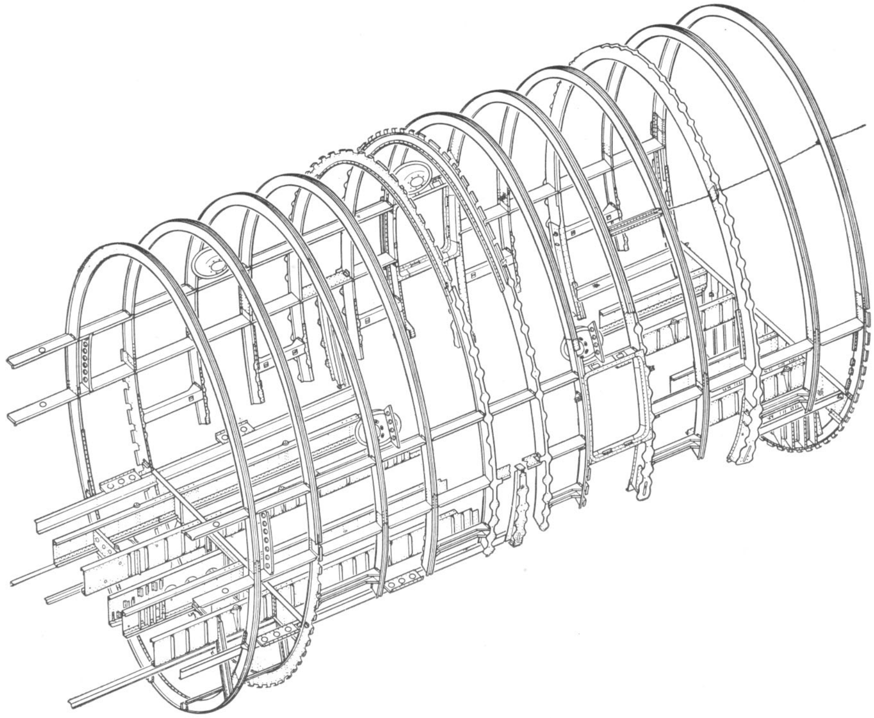


Fig. 5. Structural details of the center section frames and floor beams.

Hughes H-4 Flying Boat

Constructed entirely of wood, the huge eight-engined H-4 flying boat built by the Hughes Aircraft Co., is the largest aircraft to be built to date.

Hull frames (2) are built as a unit from the top of the fuselage to the bottom of the V-shaped keel. Fuselage construction includes former rings, stringers, reinforcing gussets, and skin (1).

Below the flight deck, fuel tanks with a capacity of 1,000 gal are installed (3).

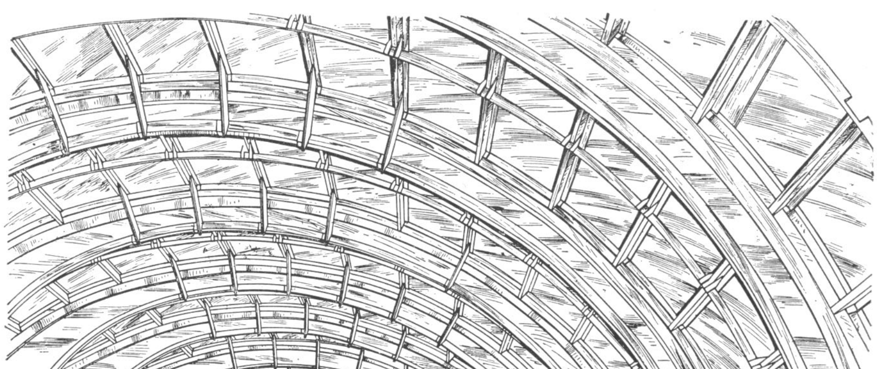


Fig. 1. Construction of former rings, stringers, and gussets in an H-4 at a point 166 ft from the nose.

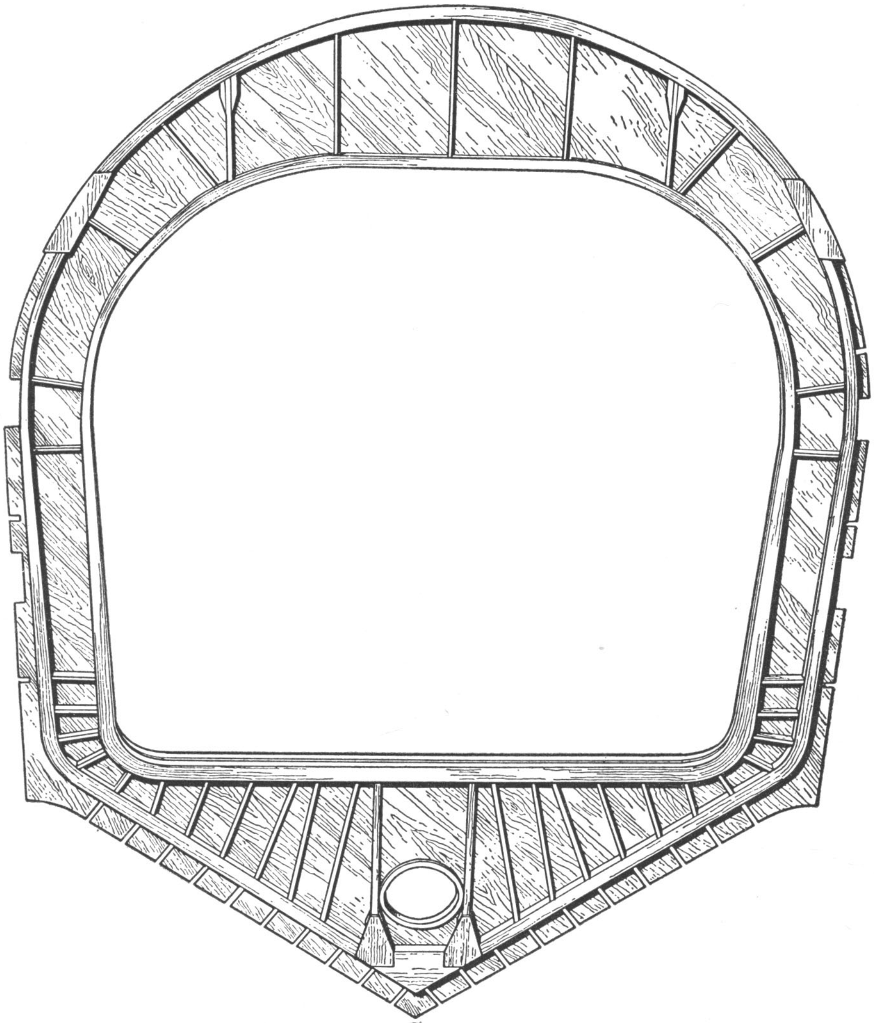


Fig. 2. A typical forward hull frame of the Hughes H-4, giant eight-engine flying boat constructed entirely of wood. The frame is built as a complete unit, from the fuselage top to the bottom of the V-shaped keel. The covering skin of one side is here removed to show the location and installation of stiffening members.

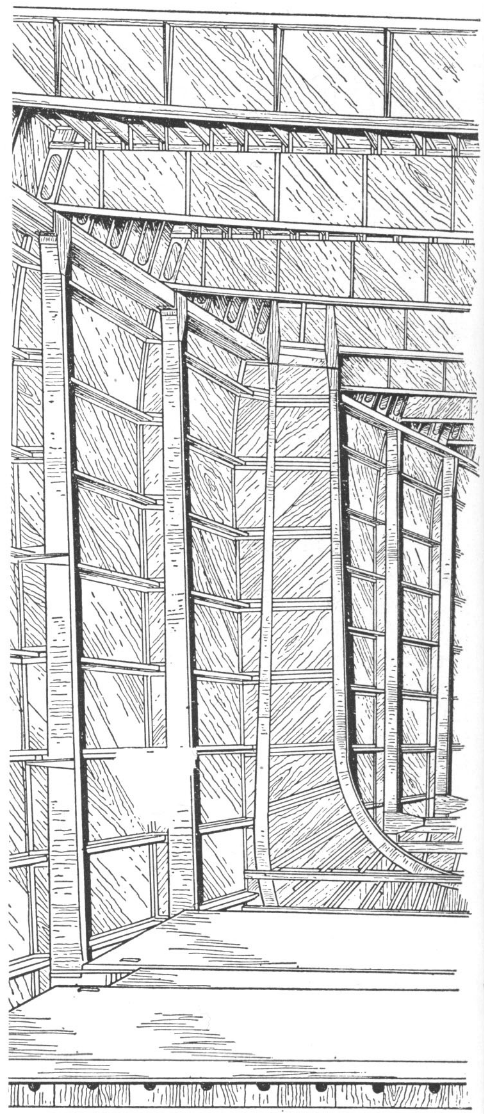


Fig. 3. Detail sketch showing the construction inside the fuselage below the flight deck of a Hughes H-4. The flooring in the foreground covers 14 fuel tanks of 1,000-gal capacity each.

Chapter V. LANDING GEAR DESIGN

PART 1. SINGLE-ENGINE AIRCRAFT

Republic Seabee

Electrol air-oil struts (1)* are utilized on the Seabee's main landing gear and are designed to have a relatively low static air pressure to facilitate servicing. Each strut is fully cantilevered from the hull side and through a bolted elbow connects with a shaft extending through the hull to the opposite gear. The hull shaft is in two sections joined at the hull center line by a welded sleeve. Channel members at each end of the sleeve provide support by extending to the frame at the hull bottom.

Strut torque arms (scissors) are utilized as step means to the cabin, and the top torque arm is designed to receive a towing hook.

Retraction and lowering of the main landing gear are accomplished by hydraulic power from an Electrol hand pump located between the cabin front seats. The reservoir, thermal expansion valve, and selector valve (flaps are also operated hydraulically) are integral with the hand pump. A bell crank on the center sleeve connecting the two sections of the hull shaft attaches to the upper arm of a two-arm toggle linkage; the lower arm of the linkage is attached to a pivot fitting on the hull structure, and above this pivot point is also connected the piston of the hydraulic cylinder. The latter is in turn pivoted on a horn attached to the center sleeve. An extension of the piston breaks the toggle linkage from a past-dead-center positive-lock position and rotates the hull shaft to retract the gear. At FULL-UP position of the gear, the linkage again comes together just past dead center to form a positive lock through contact of the positioning stops at the break point.

The tail wheel (2) is full-swiveling and is locked in the fore-and-aft position by a spring-loaded pin with cable connection to the cockpit. The wheel is mechanically raised by a cable connection to the main gear hull shaft. Cable action pulls a lockpin and then rotates a horizontal shaft on which is pivoted the lower arm of a two-arm

* The numbers in parentheses refer to the illustrations.

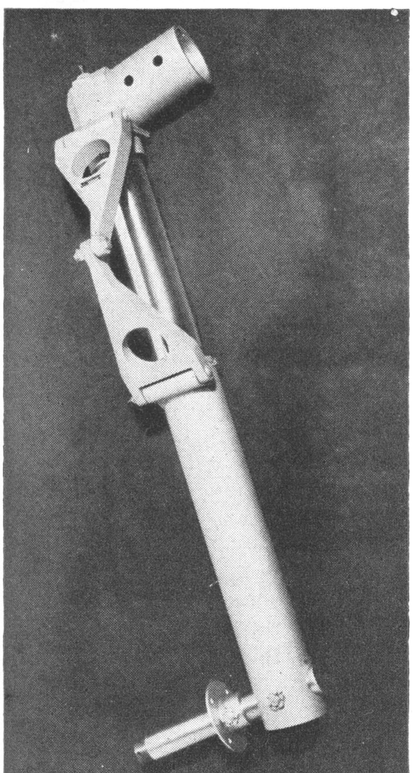


Fig. 1. Seabee main landing gear strut. The production version of this unit had a simple elbow fitting for attachment to the hull shaft.

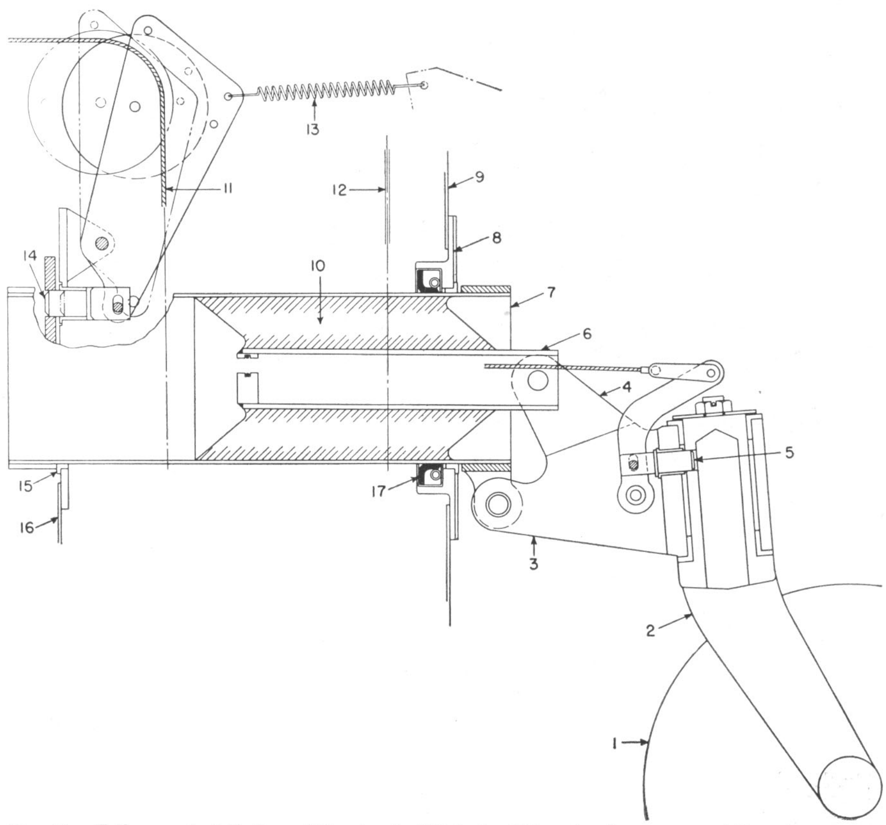


Fig. 2. Tail gear installation: (1) wheel; (2) fork; (3) yoke lower arm; (4) yoke upper arm; (5) lockpin; (6) piston; (7) hollow retracting shaft; (8) bearing; (9) second step bulkhead; (10) rubber shock absorber secured to shaft interior and piston exterior; (11) retracting cable, wound around shaft; (12) shock cord; (13) spring; (14) down-lock pin; (15) bearing; (16) forward bulkhead support; (17) spring-loaded rubber water seal. During landing, application of the ground load to the wheel (1) causes leftward displacement of piston (6) and rubber (10), then acts in shear to absorb the force imposed. In retraction cable (11) rotates shaft (7) to nest the wheel alongside the stern.

yoke on the vertical tail-wheel strut. The shaft rotates approximately 132 deg to place the wheel alongside the boom.

In addition to its tail-wheel retraction function, the horizontal shaft is designed to serve as a shock absorber for the tail-wheel ground loads. It is hollow and surrounds a piston attached to the upper arm of the two-arm tail-wheel yoke. In the space between the piston circumference and the interior circumference of the horizontal shaft is a layer of rubber secured to the piston and shaft interior surface. Upon application of the ground load to the tail wheel, the piston is displaced inwardly, and the surrounding rubber acts in shear to absorb the forces imposed.

An alteration of the tail-wheel design was contemplated, to render the unit steerable as well as swivable.

Zeke 32 (Hamp)

The outstanding feature of the Zeke's main retractable landing gear is the mounting of the retracting jack (1) to the shaft through eccentric bearings which, when the strut has completed the downward arc, brings the linkage through to a straight-line position to form a positive mechanical lock.

To retract the gear, a cable attached to a cam controlling the lock arms is operated from an extruded arm on the landing gear selector valve handle. As this is moved to UP position, the cam forces the lock arms from their position against the link plates as fluid pressure is passed to the rear of the 3- by 5-in. cylinder. As the piston connection to the leg is in straight position and as the cylinder mounting or secondary shaft is off center at the eccentric, the pressure forces the cylinder backward, rotating the shaft to bring the linkage from the straight position.

At the top of the arc a ring on the wheel fork catches a latch in the wheel well to lock it up, when a micro switch turns on a red light on the electric switch box at the left of the pilot. He must then return the selector valve to neutral position, otherwise the hydraulic pump will continue exerting pressure and the system will burn out. A warning horn blows if the pilot fails to neutralize the lever after the wheels are up and locked, but it does not blow if he forgets to lower wheels when coming for a landing. A green light on the switch box indicates that wheels are down and locked; a yellow light indicates that they are neither up nor down. There is also a small bayonet indicator which projects above the port wing to give the landing gear position, similar to the Focke-Wulfe FW-190.

Also on the wheel fork is a small trip and roller which closes and locks the fairing attached to the fuselage belly so that the retracted wheels are completely enclosed.

When the plane is on the ground and its weight causes the oleo to shorten, a flexible cable running from the right wheel up into the cockpit forces a small pin out behind the selector valve handle, thus preventing its being moved into UP position to retract the gear.

The landing gear has a spread of 11 ft 6 in.; in extended position the legs toe in 2 deg and the wheels toe out 3 deg. The brackets and fairing attached to oleo and wheels are of 0.40 gauge. Typical of the plane's light weight are the wheel and 23 by 6.9 tire, together weighing only 28 lb.

The brakes are hydraulically operated, the self-energizing type with two shoes, 9½ in. long, 1¾ in. wide, and $^{3}/_{16}$ in. thick, operating on a steel drum riveted to the wheel. The brakes are usually operated by cables running from the rudder pedals, but some of the craft have the cylinders located in the fuselage. No parking brakes are provided, apparently just to save weight.

The landing gear legs (2) are of conventional steel forging construction,

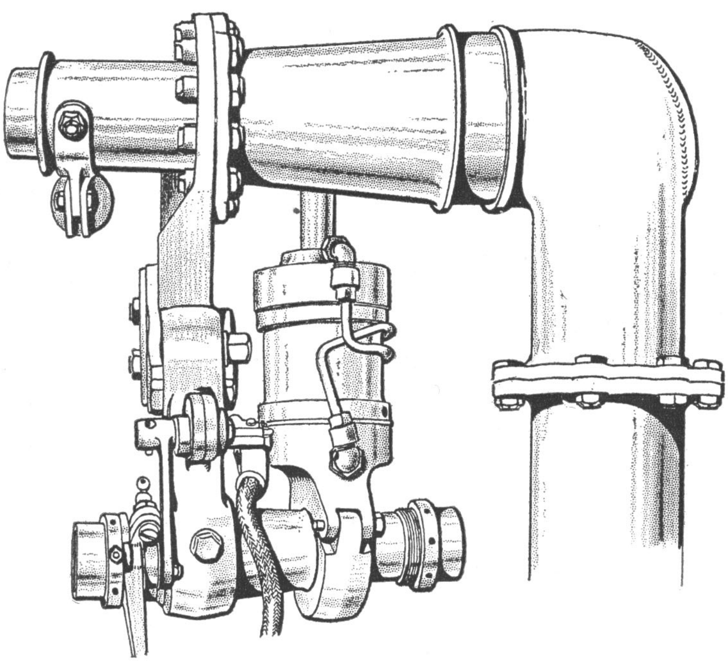
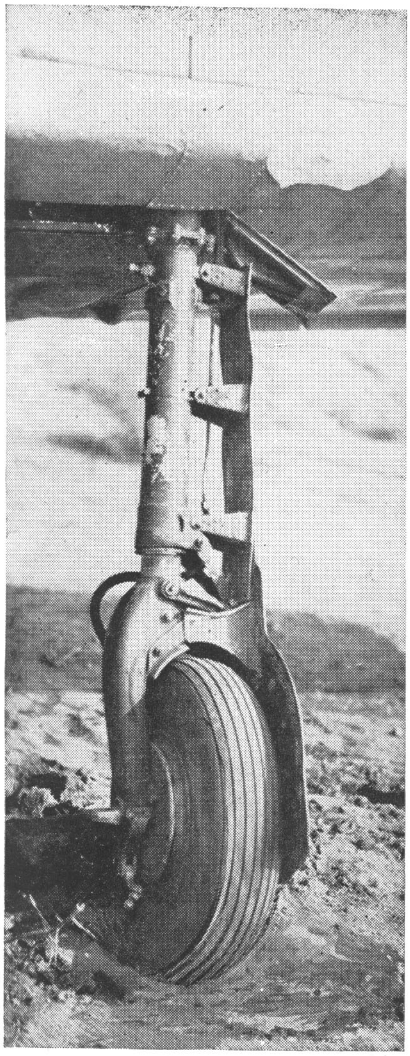


Fig. 1. A view looking down at the hydraulic jack, landing gear strut tube and pivot and locking links (at left) in retracted position. The jack piston rod is attached to a lever on the pivot shaft but hidden from view. The pivot shaft is carried on two bearings: a large one at the right and a smaller one at the left.

$3\frac{1}{2}$ in. in diameter, with oleos 3 in. in diameter having a $3\frac{1}{2}$-in. stroke and operating under approximately 230 psi, mounted atop the wheel forks of welded-steel stampings.

The retraction unit is housed ahead of the front spar in a $21\frac{1}{2}$- by $10\frac{1}{2}$-in. section built up of $\frac{1}{8}$-in. dural. Landing loads are carried directly into a short auxiliary spanwise spar and into the front spar by two heavy nose ribs, and toward the rear spar by two interspar compression struts. The built-up section puts both the landing gear leg and wheels forward of the front spar without bending it.



The tail-wheel unit (3) is a combination retracting ram and air-oil shock unit, retraction being operated by the landing gear selector valve. The light-alloy cylinder of the retracting unit houses a hollow ram, at the top of which is a piston. Just above the compression glands on the piston head is a semicircular groove. When the ram is fully extended, two round-headed, spring-loaded plungers engage in a groove and keep the ram from moving outward until pressure is exerted at the top port, indicated by (*A*) in (4).

Right below the piston is another groove accommodating 14 steel balls when the ram is fully extended. The balls are retained in a cage toward the front of, but inside, a packing gland and are pressed up against a chamfered collar by a spiral spring against a glanded collar.

The fluid pressure, supplied to the top port (*A*), also is connected with another port at (*C*) in the sketch. This pressure, in conjunction with the spiral spring, pushes the balls against the chamfered collar and forces them into a groove below the piston when the ram is fully extended.

By releasing pressure on the two ports (*A*) and (*C*) and applying it to another lower port (*B*), the unit is retracted. Owing to the chamfered edge of the groove in the ram and release of the pressure, the balls are forced back into the cage, and the ram travels back into the cylinder until locked by two plungers. All glands in this portion are of leather, there being three main sealers of V section forced between the convex and concave collar by the gland nut.

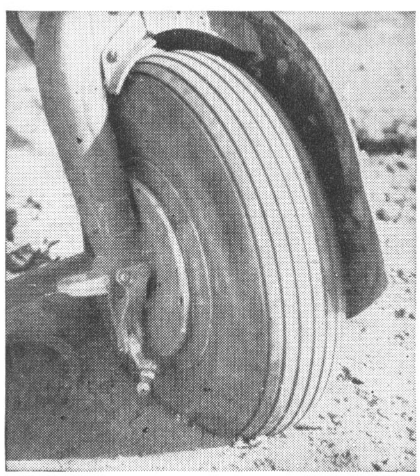


Fig. 2. Left leg of the main landing gear. The wheel fork is built up of welded-steel stamping; legs are conventional steel forgings, $3\frac{1}{2}$ in. in diameter with 3-in. oleos having $3\frac{1}{2}$-in. stroke operating under about 230 psi. The wheel and tire together weigh only 28 lb. The close-up of the wheel (2) shows up-lock latch extending inward from the axle and small ball and swivel which closes the fairing completely to cover the wheel in a retracted position.

The shock unit is in the retractor ram. From the piston end, a steel tube of $\frac{1}{2}$-in. ID and $\frac{3}{4}$-in. OD is screwed. A series of $\frac{3}{16}$-in. holes are drilled through the sides, starting $\frac{1}{2}$ in. from the end. About $\frac{3}{4}$ in. from the end is a shoulder against which is fitted a bronze collar with six $\frac{1}{16}$-in. holes bored through the face and against which a flat plate valve works to control the six holes. The bronze collar becomes a piston fitting snugly into the bore end of the other portion of the unit which in turn slides into the internal bore of the retractor ram and becomes the shock-absorbing ram at the end of which is a pivot pinhole for attaching the fuselage former *V*.

A hollow extension is fitted up the center of the shock ram, approximately $\frac{1}{2}$ in. in diameter with a $\frac{5}{32}$-in. steel tube right through the center and projecting 2 in. above the $\frac{1}{2}$-in. brass column. Fluid is fed into the unit from a charging valve through the $\frac{5}{32}$-in. tube which acts as a level tube. The brass column has a $\frac{1}{16}$-in. groove 4 in. long tapering in depth from $\frac{3}{32}$ in. at the top to zero at the bottom. This tube is a snug fit with the tube fitted to the top portion of the shock unit; in action it is a metering pin.

On impact, the shock ram moves inward, compressing the fluid and closing the valve on the piston and forcing the fluid through the metering pin groove, which in turn allows it to flow through the large holes in the side of the tube in which the pin travels to the main cylinder space. On recovering, the compressed air forces the ram outward, opening the plate valve and taking the fluid back into the original chamber.

The charging valve is situated in an offset on the end of the shock ram near the pivot hole. Gland packings in the shock unit are of fabric and a little leather.

The lower end of this retracting-shock unit is attached to the aft of the magnesium casting drag yoke (5), which is pivoted at its fore end to fuselage former *V*. Through this yoke a vertical pin $3\frac{1}{2}$ in. long turning in ball bearings attaches the aluminum wheel fork casting. The tail wheel itself is $5\frac{3}{4}$ in. in diameter and 3 in. wide and has a solid rubber tire $\frac{3}{4}$ in. thick.

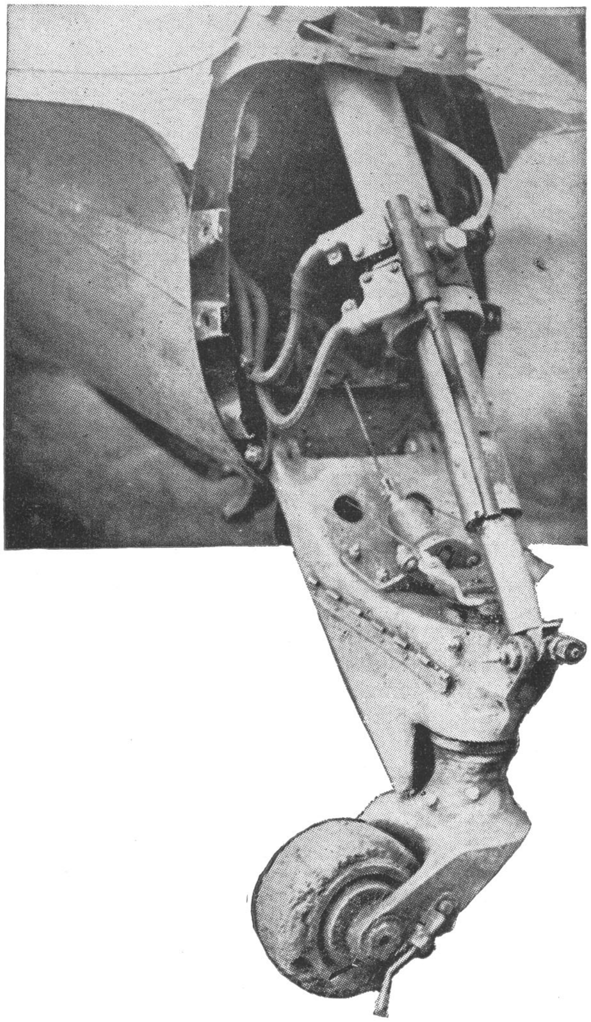


Fig. 3. A general view of the tail wheel, with tail cone removed to show castering action of the tail wheel, drag yoke, and combination retracting–shock-strut unit. The tail cone can be quickly removed with a screw driver by removing three quick fasteners, 10 screws, and the piano hinge for attaching the canvas dust catcher on each side.

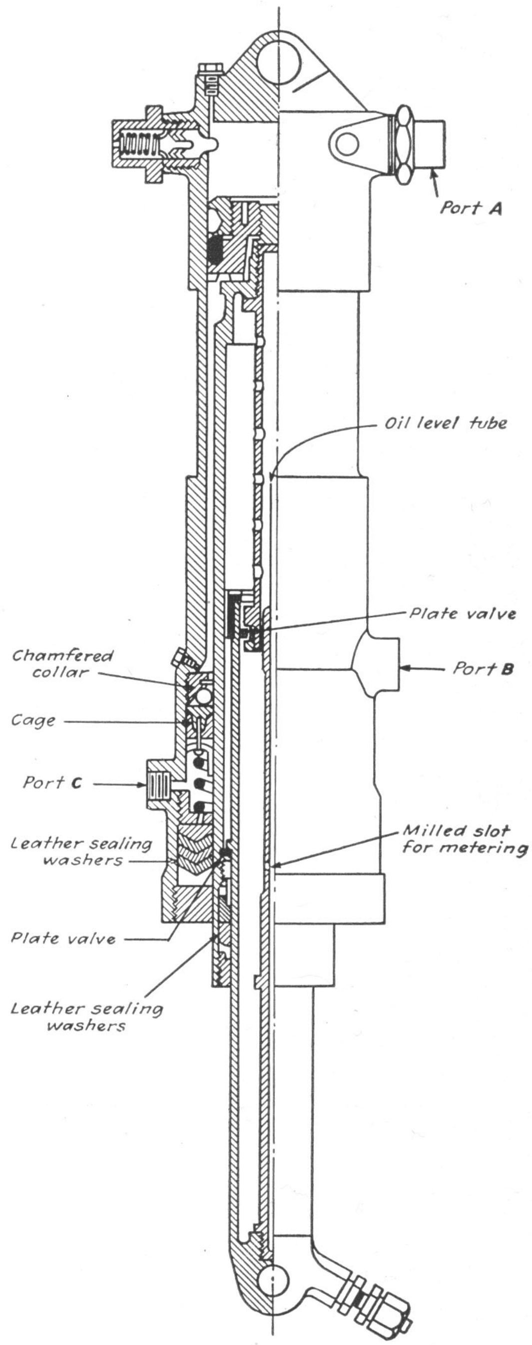


Fig. 4. A cross section of the combination shock-strut–retracting unit on the tail wheel, action of which is described in the text.

The bottom of the drag yoke is reinforced and shaped like a skid to reduce damage to the fuselage bottom in case the wheel stays retracted during a landing.

The tail wheel is steerable by cables from the rudder through an arc of about 60 deg, but full swiveling can be accomplished by giving the tail a sharp sidewise jerk which overrides the dogs tending to keep it within the normal arc. It can also be locked for take-off or landing by a cockpit-operated spring-loaded pin which drops into the front end of the steering horn.

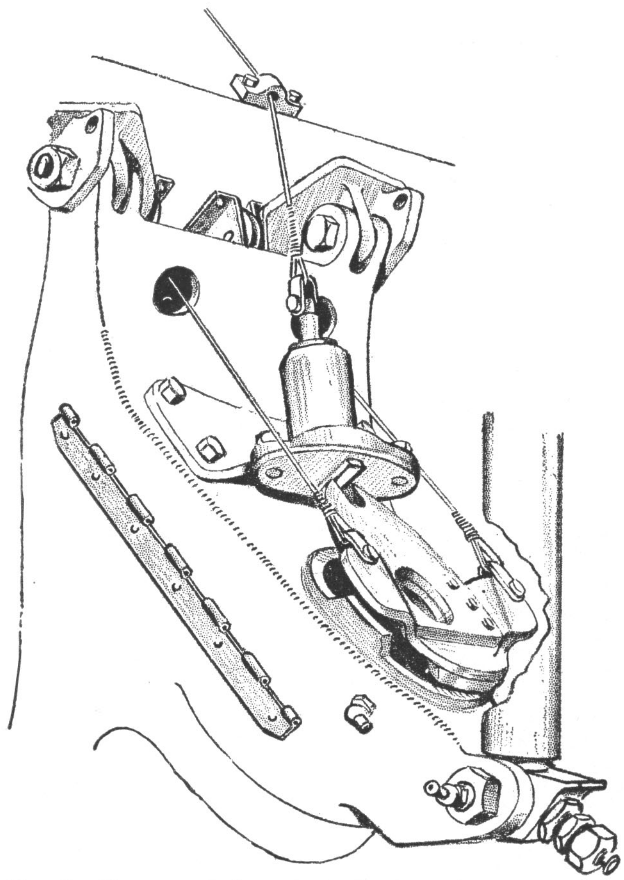


Fig. 5. Close-up of the tail-wheel drag yoke, showing the cable-controlled tail-wheel lockpin and cables for steering when the unit is unlocked. The wheel is steerable through a 60-deg arc, but full castering can be accomplished by giving the tail a sharp jerk which overrides the dogs which tend to keep it within a normal arc.

Messerschmitt ME-163

Droppable wheels are used on the Messerschmitt ME-163 rocket plane. After take-off the wheels are dropped, and a skid retracts up against the fuselage belly. The skid is extended for landing (1).

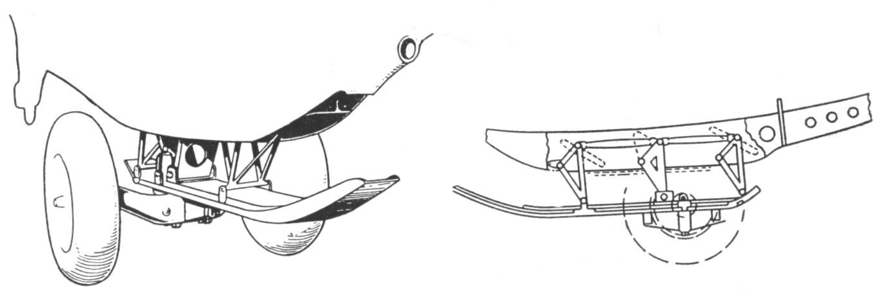


Fig. 1. The landing gear of the Messerschmitt Me-163 is shown in diagrammatic view at the right above and in perspective at the left. The wheels were dropped after take-off, and the skid retracted up against the fuselage belly for flight being extended for landing.

North American P-51

The Mustang's landing gear is three-point, with two 27-in. main wheels and full-swiveling, steerable 12.5-in. tail wheel, hydraulically retractable. The main wheels retract into wing wells, and the tail wheel into the fuselage, all fully enclosed (1).

Except for the hydraulic main gear down-lock pin, the landing gear locks are actuated from the control handle bell crank. Cables from the bell crank actuate the tail gear up-latch and down-lock pin. A push-pull rod from the lower end of the control handle works the lock system in the main wheel bay.

The main landing gear magnesium support casting is bolted to the front spar at the outboard end of the wheel well. Hydraulic struts on the front spar retract the gear inboard. A spring-loaded, hydraulically controlled pin locks the main gear down.

The tail gear is mounted on a magnesium casting bolted to lower longerons. The shock strut assembly includes the cylinder, piston, torque tube, and post housing which supports the axle. The gear is steered by cables from the rudder bell crank. Fairing doors are hinged at the side, and a link pulls them up as the gear is retracted. The tail wheel is unlocked with the stick in the forward position during taxiing and parking.

Emergency lowering of the landing gear is accomplished by pushing down the control handle at the left of the seat, also relieving hydraulic pressure in retracting struts with emergency knob in the cockpit, which causes the gear to drop of its own weight. The pilot then yaws the plane until the gears engage the down locks.

Pressure for the Goodyear multiple-disk brake is furnished by a cylinder connected to the brake by aluminum alloy tubing via a separate hydraulic system controlled by pedals. This pressure is relieved by a spring when the pedal is released. The parking brake is controlled by depressing the brake pedals and pulling the knob below the instrument panel. Pressure is retained until released by depressing both brake pedals.

Fig. 1. The left landing wheel of a Mustang: (1) shock strut; (2) fairing; (3) wheel with dust cap; (4) 27-in. tire.

Ryan FR-1

The Ryan Fireball FR-1 main landing gear retracts outboard into wells in the outer wing panel, the movement being accomplished in 5 sec. Although normally operated by hydraulic action, the landing gear is provided with two emergency stand-by systems (1).

The landing gear rib (2) is a built-up structure located at the outboard end of the center section of the wing adjacent to the wing folding joint.

The nose wheel (3) of the Fireball is designed for greater strength than is customary for land-based planes because of the severe forward-pitching moments imposed by arrested carrier landings. A Ryan-designed shimmy damper is composed of two hydraulic cylinders which allow a normal turn of 55 deg but which resist sudden movement. The nose wheel is automatically self-centering when extended by means of a cam in the oleo and is free-swiveling when the shock strut is compressed.

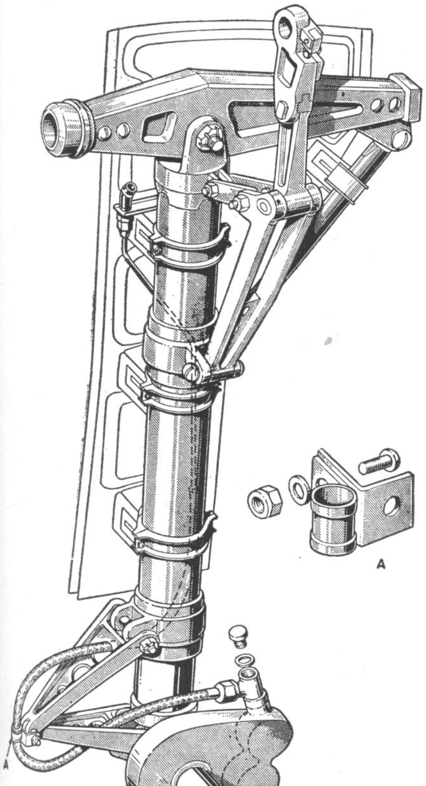


Fig. 1. The left side of the Ryan FR-1 main landing gear. The gear retracts outboard into wells in the outer wing panel in 5 sec. Normally hydraulically operated, the landing gear is provided with two emergency stand-by systems.

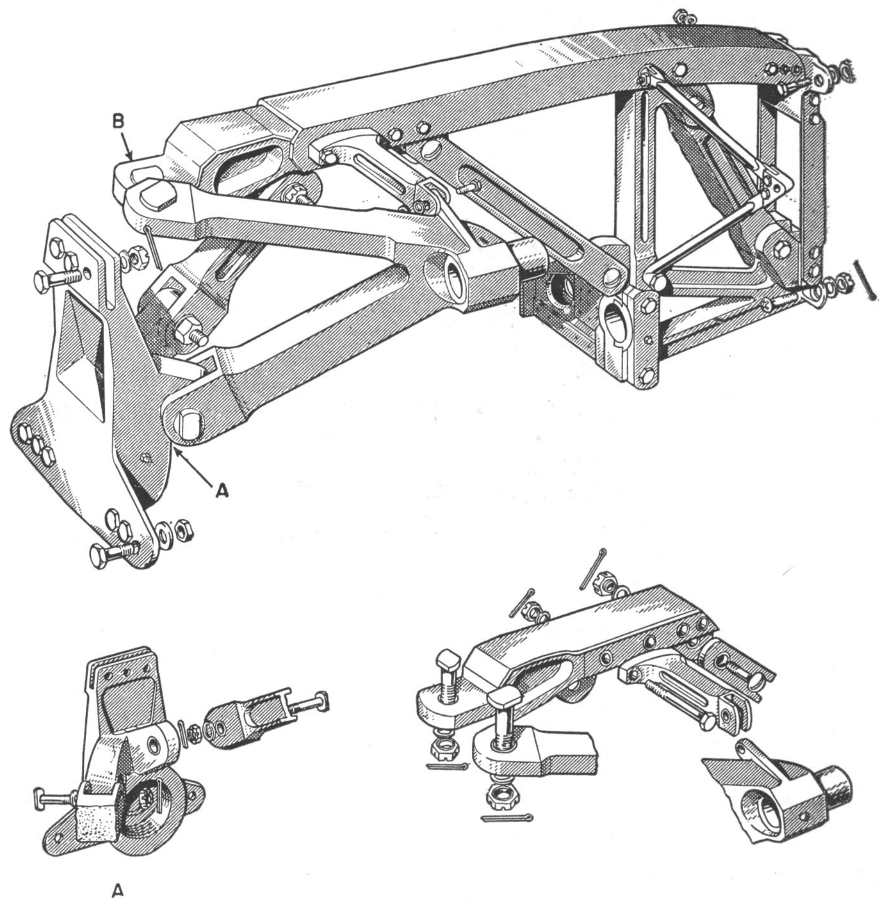


Fig. 2. The landing gear rib of the Ryan FR-1, a built-up structure, is located at the outboard end of the center section adjacent to the joint where the wings fold for carrier storage.

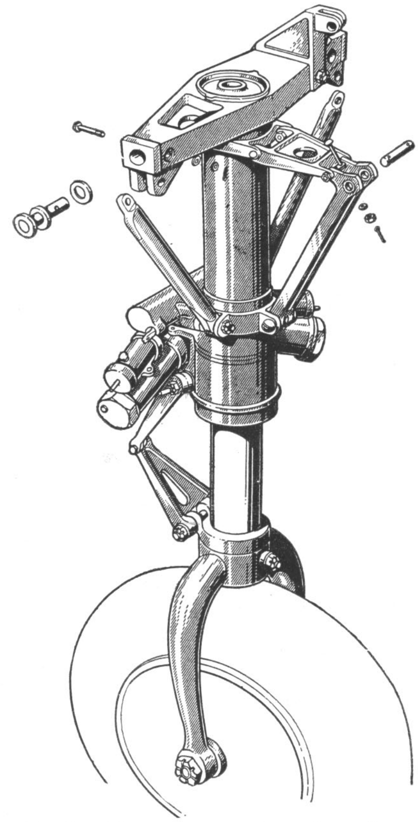


Fig. 3. The nose gear of the Ryan FR-1 retractable tricycle landing gear.

Globe Swift

The Adel landing gear used on the Globe Swift is retracted into a well just forward of the main spar (1). The gear accommodates a standard 6.00 by 6 tire mounted on spot-type wheel drums and is designed for a load factor of 4.33 on a 1,750-lb plane.

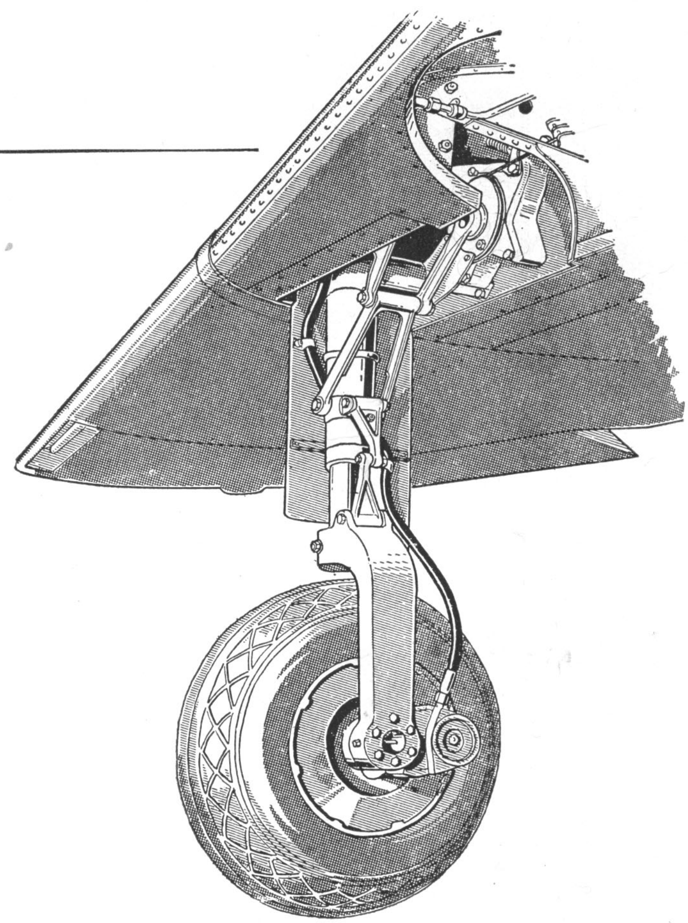


Fig. 1. Adel landing gear used on the Globe Swift.

Grumman F6F

The Grumman F6F Hellcat main gear (2) is actuated by a hydraulic cylinder through both forward torque shaft and linkage, and aft torque shaft. The aft torque shaft drives the upper drag strut by means of a spline. During rearward retraction, the wheel rotates 90 deg, the turn being imparted by a ratchet.

The retractable tail wheel of the F6F is attached to the aft face of a bulkhead and includes a hydraulic retracting cylinder which is attached to the main shock strut (1).

For carrier operations, the F6F is provided with an arrestor gear installation (3). Extension and retraction of the hook are by means of an electric motor turning a sprocket to move a chain and cable. The hook assembly moves along a track, and a spring keeps the hook down when the unit is extended for carrier landing.

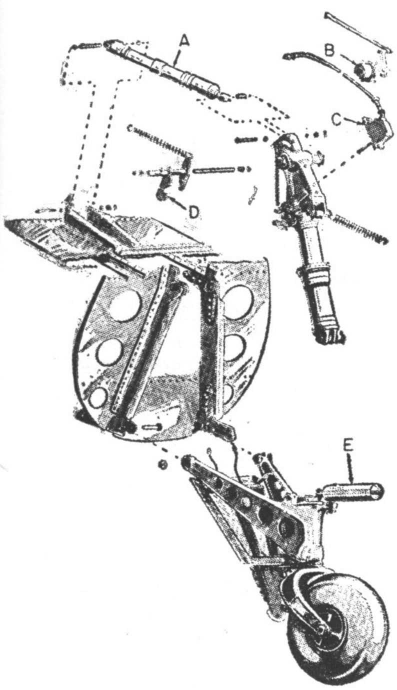


Fig. 1. Exploded view of the F6F retractable tail wheel in relation to the bulkhead to which it is attached: (*A*) hydraulic retracting cylinder; (*B*) position indicator; (*C*) warning switch; (*D*) up lock; (*E*) wheel centering mechanism.

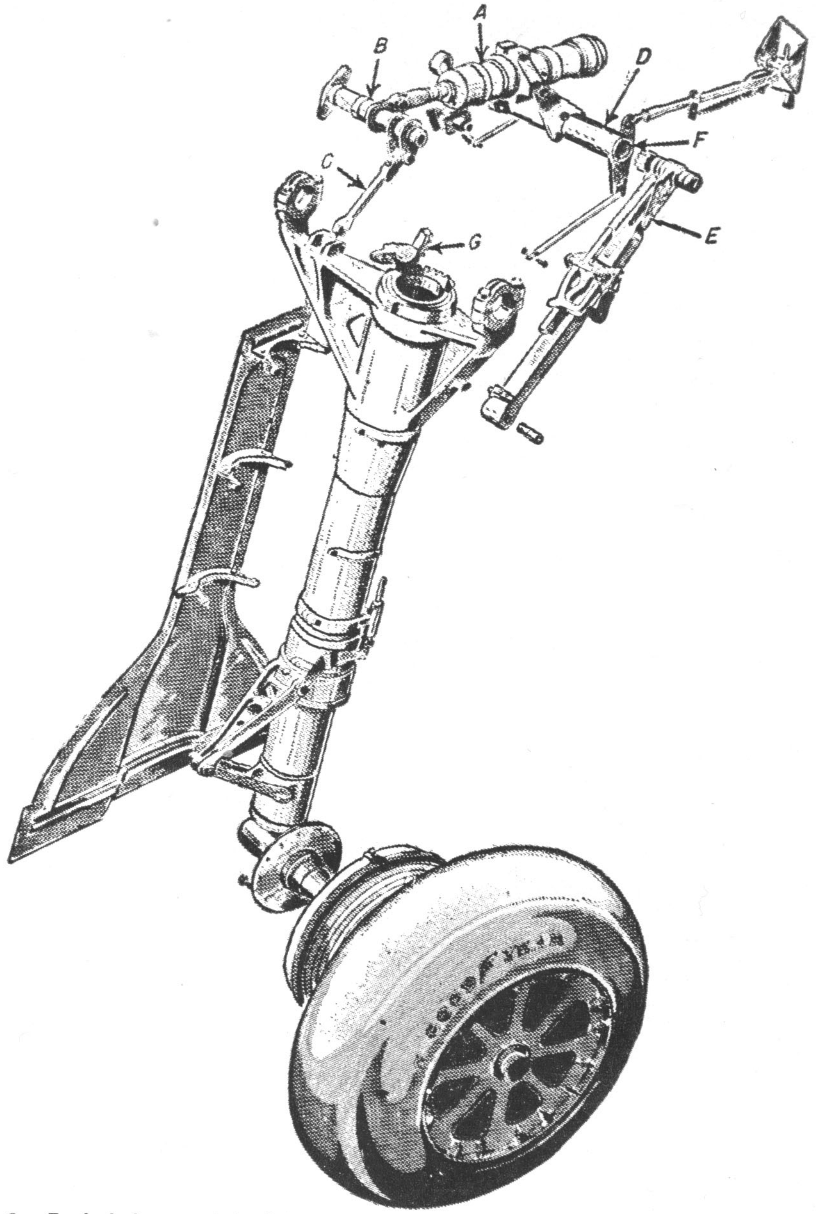


Fig. 2. Exploded view of the left main landing wheel of a Grumman F6F Hellcat. The hydraulic cylinder (*A*) actuates gear through both forward torque shaft (*B*) and linkage (*C*); and the aft torque shaft (*D*) which drives the upper drag strut (*E*) by means of spline (*F*). During rearward retraction the wheel rotates 90 deg, the turn being imparted by ratchet (*G*).

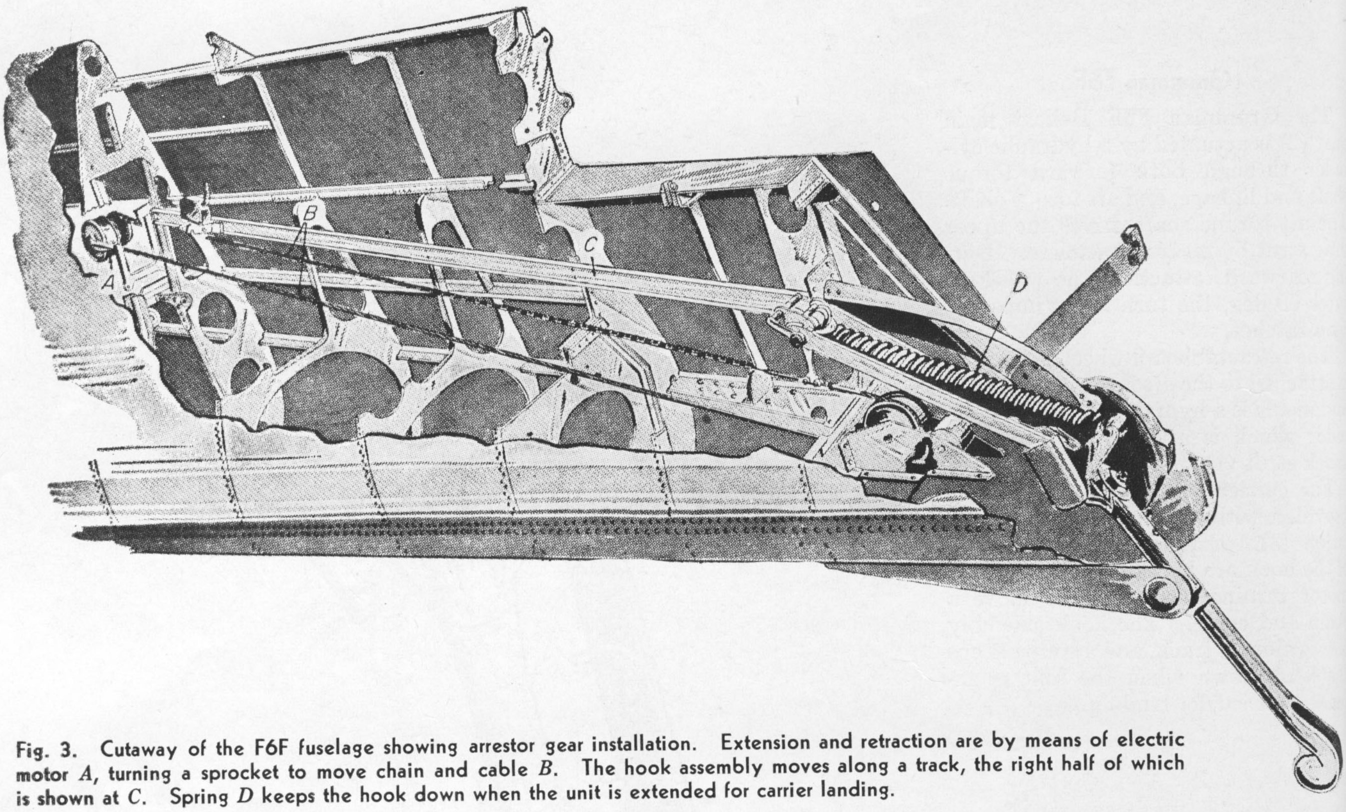


Fig. 3. Cutaway of the F6F fuselage showing arrestor gear installation. Extension and retraction are by means of electric motor *A*, turning a sprocket to move chain and cable *B*. The hook assembly moves along a track, the right half of which is shown at *C*. Spring *D* keeps the hook down when the unit is extended for carrier landing.

Fleetwings BT-12

The BT-12 trainer landing gear is of fixed type, single leg, half fork, and uses air-cooled struts (1). Interchangeable wheels are aluminum alloy castings, equipped with Bendix hydraulic brakes and mounting 27-in. smooth-contour tires designed for 32 psi. The moving sections of the shock leg are covered by a flexible canvas cover to exclude dirt. The axles are steel tubes, also interchangeable left and right.

The tail gear (2) is a steerable, full-swiveling nonretracting wheel on a half fork with air-oil shock strut fastened to the fuselage at its upper end by one bolt. The yoke is fastened by a bolt at each side. Tail wheel tire pressure is maintained at 45 psi.

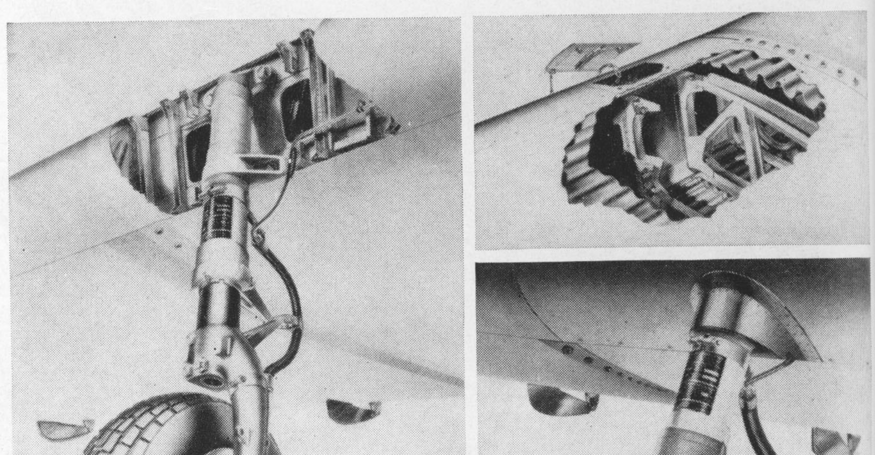


Fig. 1. The landing gear is attached to the center section spar by four AN10 bolts. When in service, moving parts of the shock leg are protected by a flexible canvas cover.

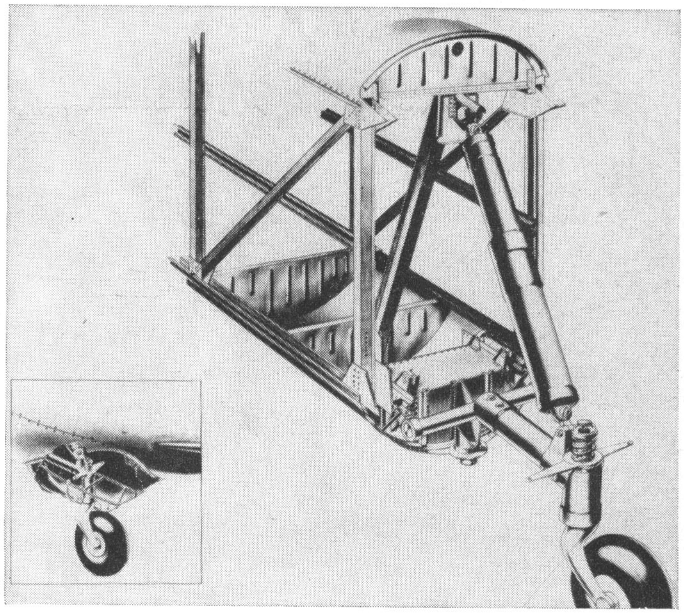


Fig. 2. The tail wheel is steerable, full-swiveling, nonretractable and attached to the fuselage by one AN6 bolt at the upper end of the shock strut and one AN4 bolt at each side of the yoke.

Focke-Wulfe FW-190

A single-strut oleo shock unit, with conventional torque scissors, the FW-190 main landing gear is attached to a forged-steel tapered roller-bearing spindle assembly. The front face of the mounting is flanged to bolt to the front spar. The fairing is in three sections: one attached to brackets extending up from the hub; another bolted to the oleo strut; a third hinged at the fuselage center.

A scale (1) painted on the two fairings attached to the landing gear tells at a glance if proper pressure—about 1,300 psi—is being maintained in the shock strut.

Retraction is electric, with a separate unit for each wheel. The motor (2), which turns up 14,000 rpm, is mounted back of the front spar web, with a 3.3:1 reduction from the armature shaft, then a safety centrifugal clutch, followed by two gearless reductions, one 53:1, the other 60:1, giving a total reduction of 10,491:1 in three steps in a unit 14 in. long and, at the front end, 7 in. in diameter.

The last reduction stage—at the front face of the spar web—drives a forged-steel ring $1\frac{3}{8}$ in. thick to which is yoked a tapered aluminum alloy I beam, $13\frac{3}{4}$ in. long. This in turn is jointed to another tapering beam into

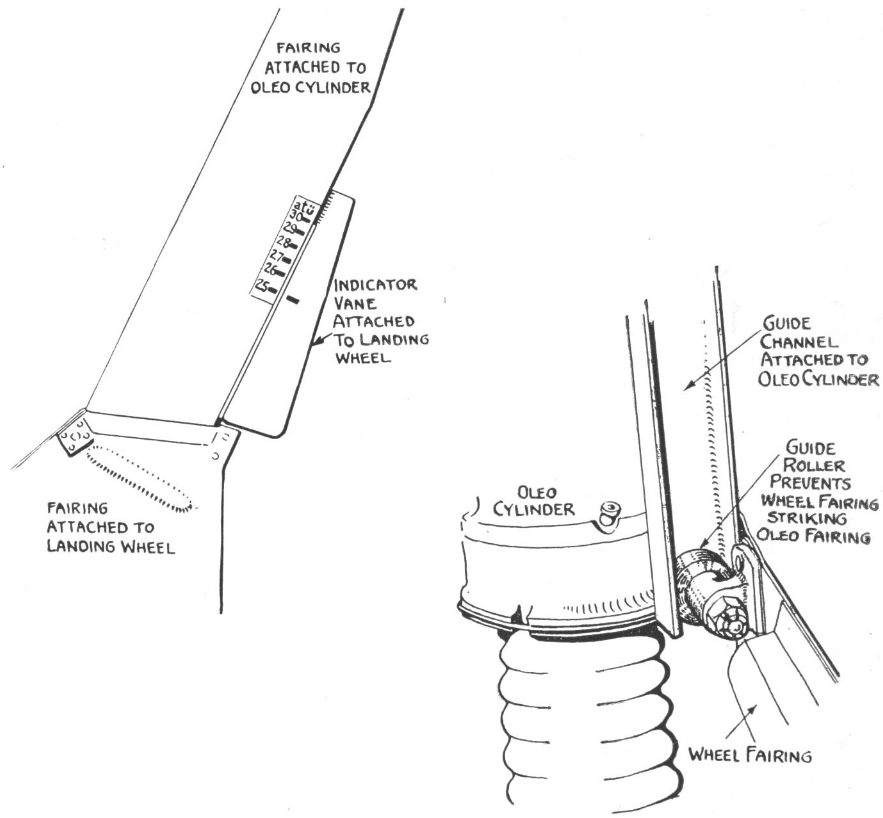


Fig. 1. Detail sketch showing pressure-indicating marks on the main landing gear fairing. The lower part of the vane moves with the wheel; the upper part is attached to an oleo cylinder. The scale is graduated in atmospheres, 25 to 30 being the range.

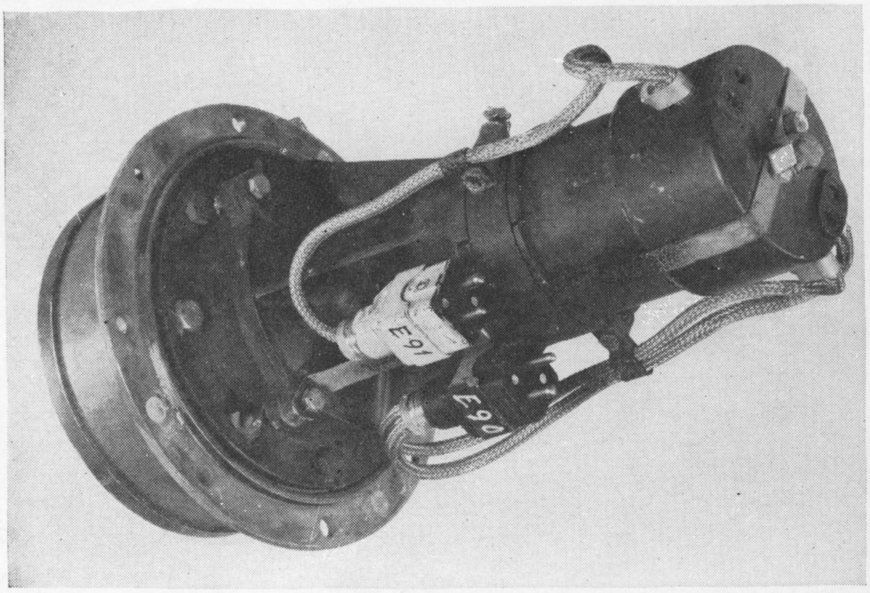


Fig. 2. The main landing gear retracting motor and reduction gear, with boltholes where it is attached to the front spar.

the lower end of which is screwed a ball-and-socket joint that attaches to the oleo strut.

The forged ring turns outward to lower the wheels, and the arms, because of their toggle action, lock the landing gear down. When turned toward the airplane center line, the joint between the I beams or toggle arms breaks to pull the oleo and wheel up and inward.

In the down position, the oleo struts have not yet reached the perpendicular, and there is no down lock on the gear. The two I beams form a straight line when the gear is down, and this straight thrust, coupled with the high reduction from the motor, appear to suffice for the gear down locking.

Small metal contacts through fiber insulation on the faces of the I-beam joints automatically shut off the motor when the landing gear is full down. On the rotating member of the landing gear mechanism, there is a small scaled rod (3) which projects up through a ball joint in the top of the wing as the gear goes down so that the pilot can tell the exact position of each wheel.

The oleo strut just above the wheel contacts a coupling (set in a box structure mounted on the front face of the front spar) which snaps into place as the gear retracts, locks the gear in up position, and automatically shuts off the retraction gear motor. The lock is held closed by an electric latch and releases electrically when the power is turned on to lower the wheels. Manual operation, however, can unlock the wheels. The pilot pulls a knob, on the

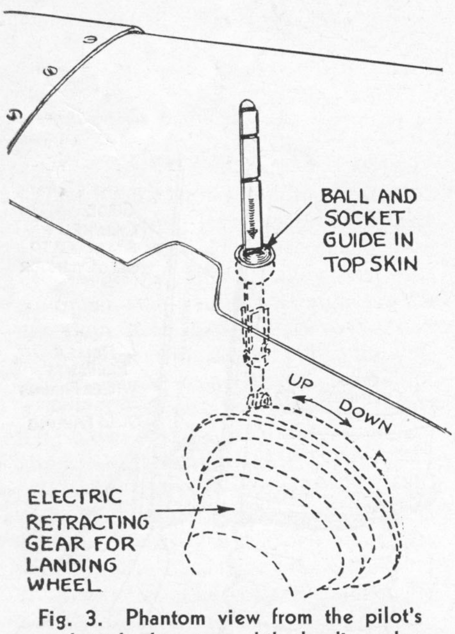


Fig. 3. Phantom view from the pilot's cockpit, looking toward the leading edge of the wing and showing the landing gear position indicator. It is entirely mechanical, like a bayonet oil gauge. It slides through a slotted ball in the top wing skin and disappears when the landing gear is fully retracted.

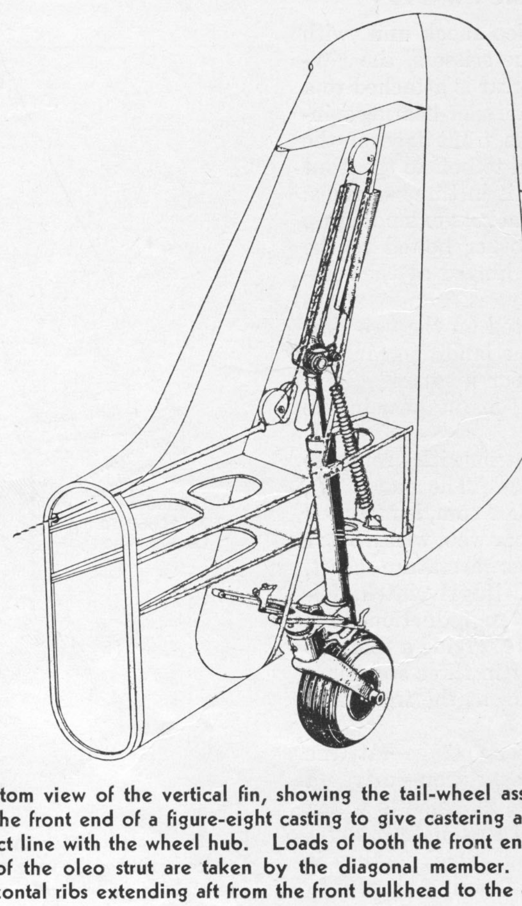


Fig. 4. Phantom view of the vertical fin, showing the tail-wheel assembly. A wheel fork is set in the front end of a figure-eight casting to give castering action, but the oleo strut is in direct line with the wheel hub. Loads of both the front end of the drag yoke and the top of the oleo strut are taken by the diagonal member. A stabilizer goes between horizontal ribs extending aft from the front bulkhead to the diagonal member.

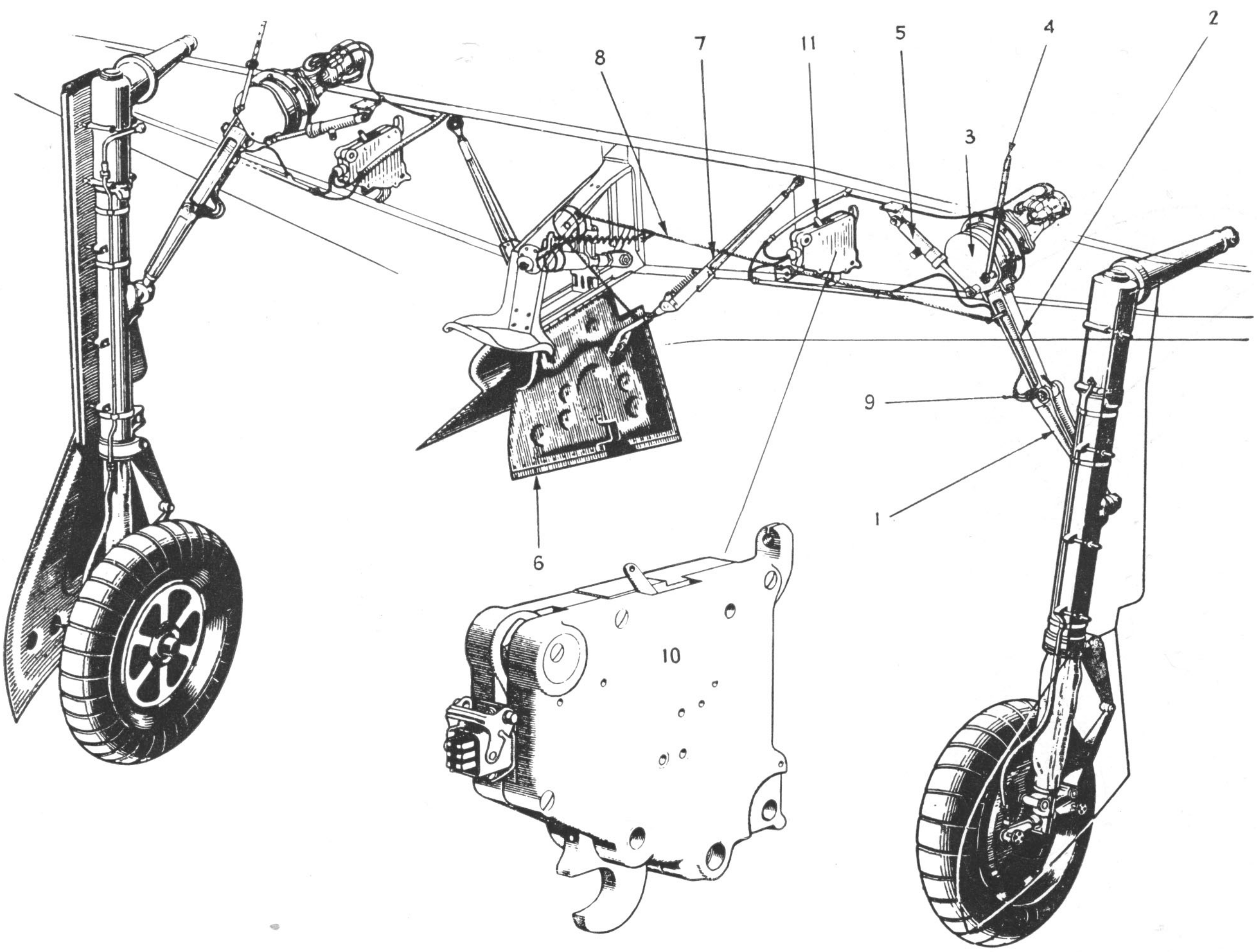


Fig. 5. Main landing gear, showing how the wheels are hinged from the front spar. Retracting gear arms (1) and (2) are attached to electric motor-driven drum (3) to which are attached a mechanical position indicator (4) and dashpot (5). Fairing (6) is pulled up into place when the landing gear strikes arm (7). A steel cable (8) running from the retracting gear arm in over the pulley at the center line straightens arm (7) to hold the fairing in open position when the wheels are down. Switch (9) between the retracting gear arms cuts power off when the wheels are down. When retracted, the gear is secured by the latch down at the bottom of the detail sketch (10). This unit also carries a switch to cut off power when the wheel is latched up. A cable attaches to lever (11) to release the latch in case of power failure, when the wheels go down by gravity as the motor is disconnected when the power is off.

left side of the instrument panel, attached to a flexible cable which, atop the center of the front spar, is yoked to similar cables leading out to each landing gear up-lock box (5).

Retraction of the tail wheel is automatic with that of the main gear. At the joint of the two I beams on the right main wheel is attached a cable that runs over a pulley set just above the gear spindle, thence inboard along the spar front to the right side of the fuselage—in a conduit through the cockpit—back to a pulley on the front of the diagonal "heart" member in the fin, then up over a pulley atop it and down to a yoke set at the top of the tail-wheel oleo. Thus, as the main gear joint starts to move up, tension on the cable is transmitted back to the tail-wheel retracting mechanism, and the wheel is pulled up. A similar cable arrangement is used to pull the camera protecting door open when the landing gear is retracted. The center wheel fairings are held tightly open by a cable system when the landing gear is down and are closed by the wheel when it is retracted (6).

The tail wheel itself is mounted in a steel fork which fits into the front end of a very heavy steel figure-eight casting which places the center of the yoke 6 in. ahead of the wheel center to permit castering. The tail-wheel drag yoke attaches to the diagonal empennage member and to this figure-eight casting just ahead of the bottom of the oleo strut, which fits into the aft portion directly over the wheel center (4).

At the top of the oleo strut is a yoke containing four rollers: two load-carrying large ones set on each side of the center, and two smaller locking ones just aft. These rollers run in the channel member on the aft face of the diagonal member and are part of the yoke to which the retracting cable attaches and to which is also attached a coil spring going down and aft to the rib holding the lower rudder hinge. This spring—and gravity—pull the unit down. At the bottom of the channel the track leads forward, just enough for the larger rollers to fit into the resulting "pocket" so that loads from the tail wheel are transmitted up

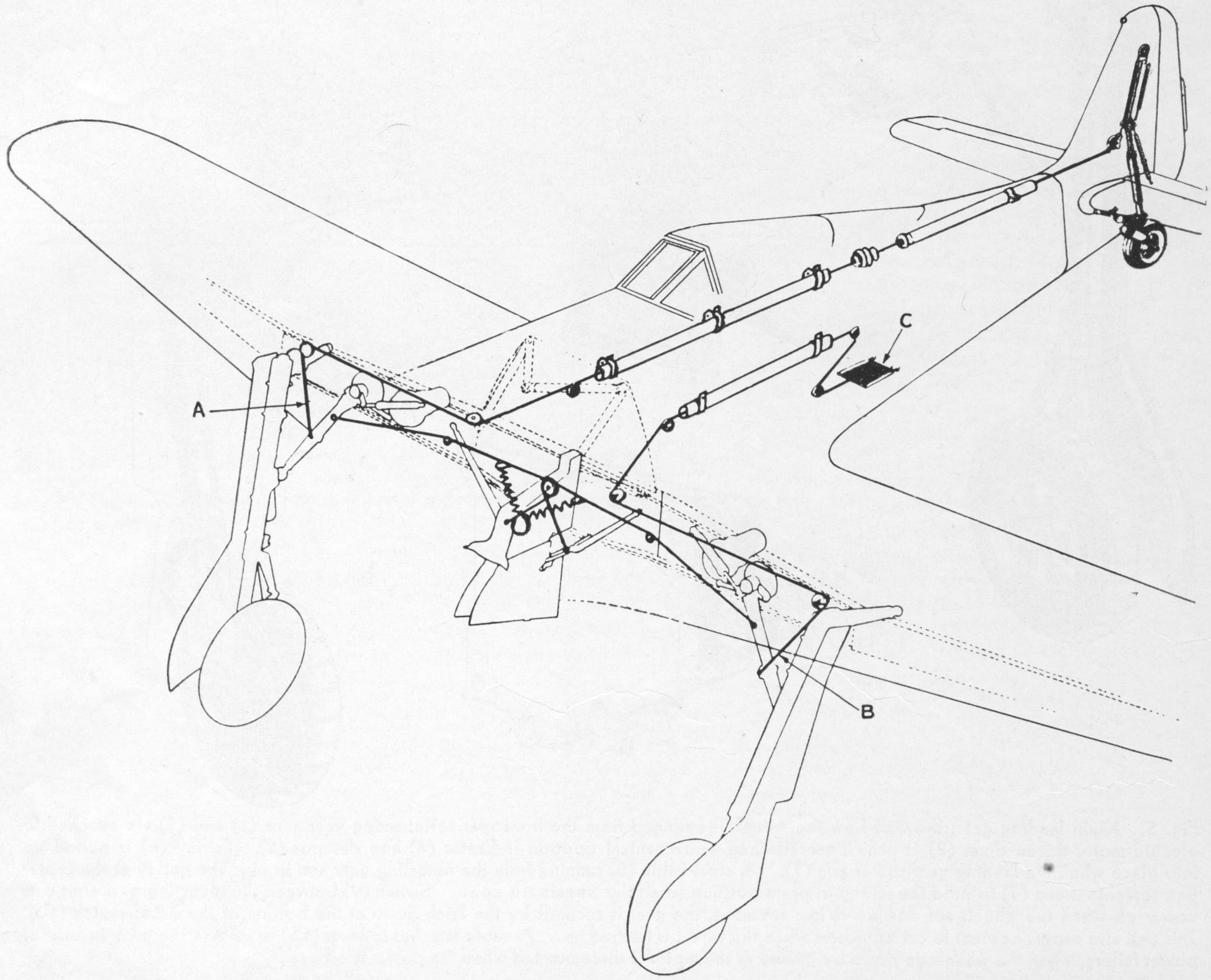


Fig. 6. Phantom view showing how the tail wheel is automatically retracted with the main gear. As the right wheel moves up, it tightens cable *A*, which goes up over a pulley, inboard to the right side of the fuselage, then aft through conduit to the vertical fin diagonal member, up over it to pull up on the yoke attached to the top of the oleo. As the left wheel moves up, it tightens cable *B* to open sliding door *C* under the cameras.

through the oleo directly against and toward the front of the diagonal rib, thus locking the wheel in DOWN position. When tension is put on the cable from the main gear, it starts the smaller rollers up the channel, and they in turn pull the larger ones out of the "pocket," to unlock the gear, and then up the track (7).

The tail wheel moves up 20 in., and rubber pads on the axle just outside the fork fit snugly against the bottom fuselage skin when it is retracted. A spring-loaded V cam centers the wheel as soon as the load is released.

An interesting detail of the tail-wheel castering unit is this: The pivot is a hollow steel forging welded to the fork, and the hollow space is utilized as a grease reservoir for lubricating the swivel surface, the grease coming out through a slot 3 in. long which also serves as the tail-wheel lock.

The main landing gear tires are 700 by 175 mm, smooth contour; the tail wheel tire, also smooth contour, is 350 by 135 mm.

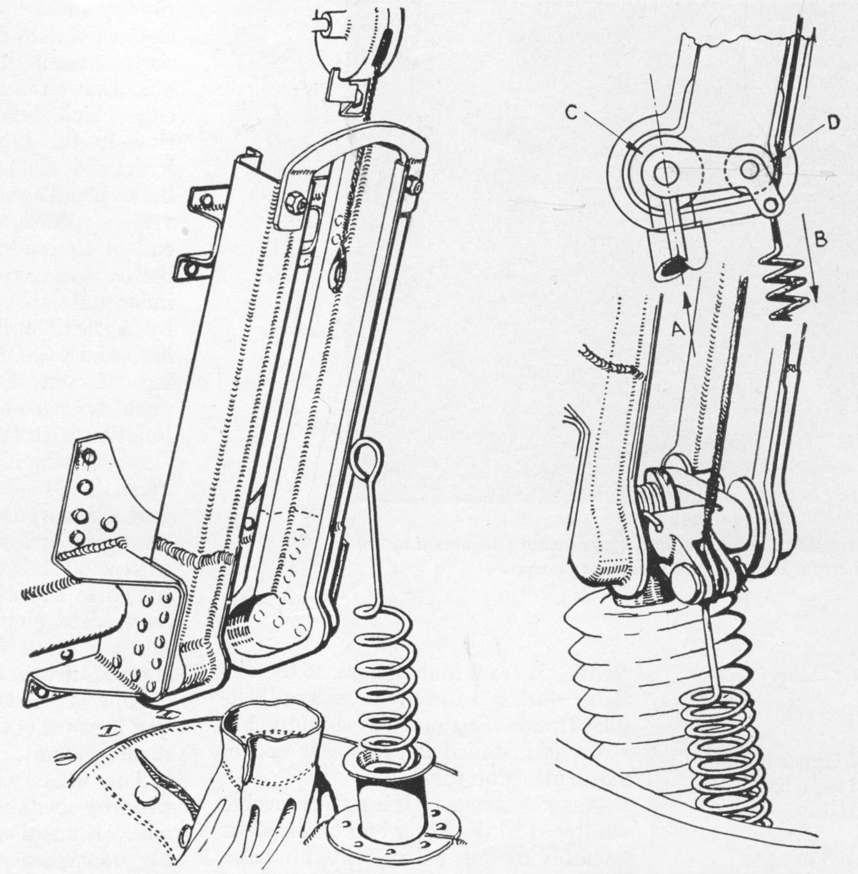


Fig. 7. Details of the tail-wheel retracting gear and roller locking device. At the left is the track (with oleo and lock removed), which is riveted to the aft face of the diagonal member of the assembly. The oleo would extend up through the dust-catching fabric with bellows attached to the top. Also shown is a metal tube to prevent the coil spring from injuring the enclosing material. The sketch at the right shows gear in place and locked in DOWN position; in the upper right the method of locking is shown diagrammatically. *A* is the direction of the load thrust, *B* is the direction of pull by the coil spring. This pulls trigger roller *C* down into locking position, forcing large roller *D*, which takes the landing load thrust from the top of the oleo, into its DOWN position.

Bell P-39 Airacobra

Equipped with a fully retractable tricycle landing gear, the Airacobra's nose wheel is a self-castering, nonsteerable type which retracts up and aft into the foreward fuselage (1); the main wheels retract up and inboard into the outer wing panels. The retracting mechanism is operated by an electric motor through a system of torque tubes, universal joints, gearboxes, and splined connections. The operation of the landing gear motor is governed by a toggle switch in the pilot cockpit. In the event of power failure, the wheels can be operated by an emergency ratchet crank at the right of the pilot's seat. General specifications of the landing gear are as follows:

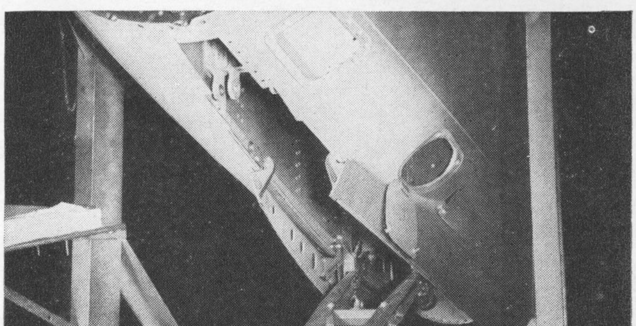


Fig. 1. Retracting link and wheel well for the nose wheel in the forward fuselage.

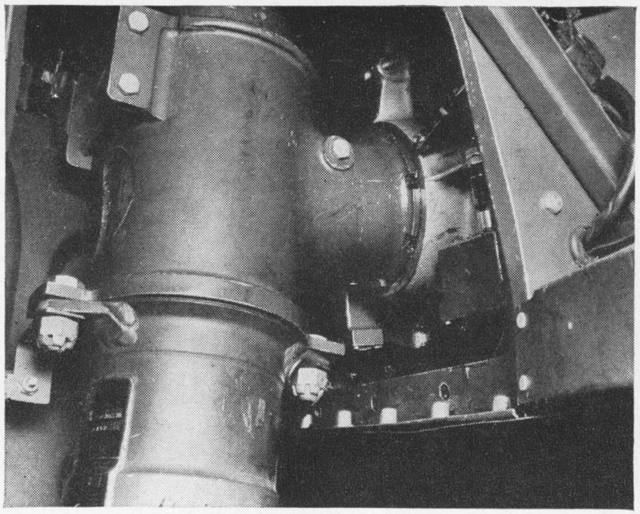


Fig. 2. Close-up of the main landing gear strut attachment to the spindle at the rear beam of the outer wing panel.

Landing Gear Data

Type	Tricycle
Wheel construction (all wheels)	Magnesium alloy
Wheel base	119¾ in.
Tread	136 in.
Main gear oleo travel:	
Total	8 in.
From extended to static	5 in.
From static to compressed	3 in.
Nose wheel oleo travel:	
Total	10 in.
From extended to static	7 in.
From static to compressed	3 in.
Nose wheel swivel (either side of plane of symmetry)	60 deg
Main wheel diameter	26 in.
Nose wheel diameter	19 in.

Air-oil shock struts used on both nose and main gear are Cleveland pneumatic. The main gear struts are attached to a fitting of the spindle assembly in the wing panel by four nuts and bolts (2). The forged-steel landing gear fork is attached to the pistón tube of each strut which operates with the wheel. Conventional torque scissors are used on the main and nose wheel installations.

The nose wheel shock strut is hinged to the forward fuselage inside the nose wheel well and is retracted by a linkage assembly. A centering cam is installed in the oleo strut keeping the wheel in a central position and preventing it from fouling against the airplane during retraction. An adjustable Houde Engineering shimmy absorber is installed in the lower end of the strut piston tube.

The nose-wheel fork is a steel forging connected to the lower end of the strut assembly by four bolts, located in pairs at the front and rear of the fork, and lock-wired in pairs. Holes are tapped in the lower end of the piston tube and lined up with the fork boltholes.

The nose wheel is mounted on a chrome-moly-cadmium-plated steel tube axle, which slides through the fork ends from left to right and is held in place by a large nut lock-wired to the fork. The tire is 19 in. in diameter with a high-pressure dual-seal safety tube.

Oil- and gas-resistant, pliable rubberized boots are fastened to each wheel strut assembly with a crisscross lace. At the top they are held by fairing clamps and at the bottom by two slots into which the two fork-to-scissors brackets are inserted.

The main wheels are magnesium alloy equipped with disk-type hydraulic brakes. Tire casings are 26 by 6 in., six-ply rayon, with high-pressure punctureproof tubes. Three types of interchangeable tires are used: treaded for ice- or snow-packed fields, flat contour for desert or sandy fields, and smooth contour for normal operations.

Each main-wheel brake assembly has eleven plates, six stationary steel disks, and five movable brass disks. The stationary disks are held in place by six slots on the inner side which slide over six tongues on the axle hub. The movable disks have six tongues on the outer edge which slide into six corresponding slots in the brake drum. A Warner hydraulic master brake cylinder and brake pedal assembly are mounted in a vertical position and pivoted on each end of the rudder control pedal cross bar in the cockpit. Master brake cylinder units are connected to the brakes by a flexible leather-covered rubber hose and 5⁄16 OD aluminum alloy tubing. A control on the main instrument panel operates a parking brake in conjunction with the main wheel brakes.

A reversible, 24-volt motor, giving ¾ hp at 3,800 rpm, operates the landing gear. Incorporated in the assembly are a clutch and reduction gear drive with a 40:1 ratio. The clutch is designed to slip at an output torque (at slow speed shaft) of 700 in.-lb. The motor is mounted on the forward fuselage deck at the right side of the engine. An operating control switch is mounted just forward of the left-hand cabin door in the cockpit.

The main wheels retract into the wing by means of a worm sector gear which is installed with a spindle assembly on the aft face of the rear main beam by 12 nuts and bolts lock-wired in pairs. Each strut is attached to a fitting of the spindle assembly by four nuts and bolts. A worm gear installed

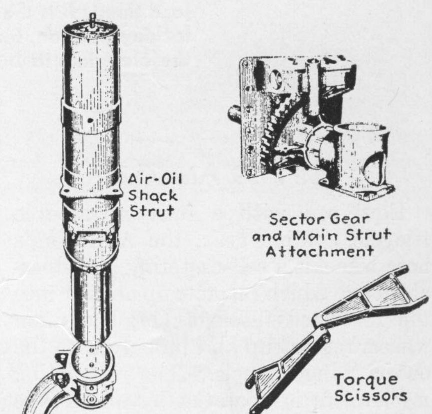


Fig. 3. Component parts of a main landing gear strut and brake assembly.

in the spindle assembly is actuated by the landing gear motor by means of torque tubes. The worm gear rotates the sector gear, which in turn retracts or extends the wheels. Elements of the main wheel and brake are shown in (3).

The nose-wheel retraction mechanism consists of a retracting screw installed in the forward fuselage and driven by the landing gear motor through torque tubes and a 90-deg gear drive. This actuating screw is attached to the main leg of the nose wheel linkage assembly. A coupling shaft links the retracting screw and gear drive.

The retracting linkage consists of a short link, attached to the oleo strut, to which is hinged a large or main link, hinged in turn to two A-frame fittings in the fuselage. Details of the nose-wheel retracting elements are shown in (4).

The emergency handcrank is equipped with a ratchet and can be reversed by a switch at the top outboard face of the crank. A clutch handle is located just aft and outboard of the handcrank on the cabin floor, to change from electric to manual operation, or vice versa. A schematic arrangement of the landing gear and its control system is shown in (5).

The main-wheel fairing is made up of three sections. Two are attached to the main-wheel strut at two points. The lower section of the fairing laps over the upper section, but the two are not connected in any way, the overlap permitting motion of the oleo strut without damage or buckling. The lower section is attached at the main-wheel axle by a washer and castellated nut and to the upper portion of the fork by a link assembly. The upper section of the fairing is attached to the strut in two places by clamps. Five bolts hold the lower clamp, and four hold the upper clamp to the fairing. Each clamp is held to the strut by a bolt and lock nut.

The third section of the fairing, known as the "flipper door," is hinged to the lower surface of the wing center section, near the wing splice bulkhead. It opens toward the airplane center line and is actuated by the main wheels during extension and retraction. The wheel extends and allows the spring-loaded arm of the door to straighten, forcing the door open. Upon retraction, the tire comes in contact with the spring-loaded arm and causes it to fold upward, drawing up the door.

The nose-wheel fairing is in two sections. One is bolted to the top of the nose-wheel strut and lies flush with the undersurface of the fuselage when the wheel is retracted. The other section consists of right- and left-hand doors hinged to the forward fuselage at four hinge points. These doors are actuated by a spring-loaded arm in a manner similar to the main-wheel fairing doors.

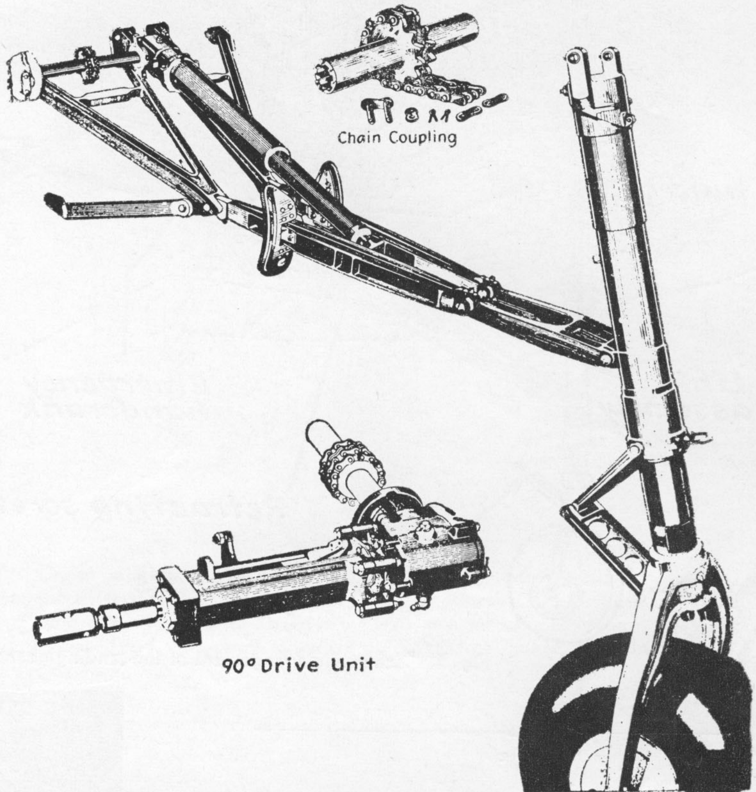


Fig. 4. Component parts of the nose wheel gear assembly. The nose wheel retracts in unison with the main gear.

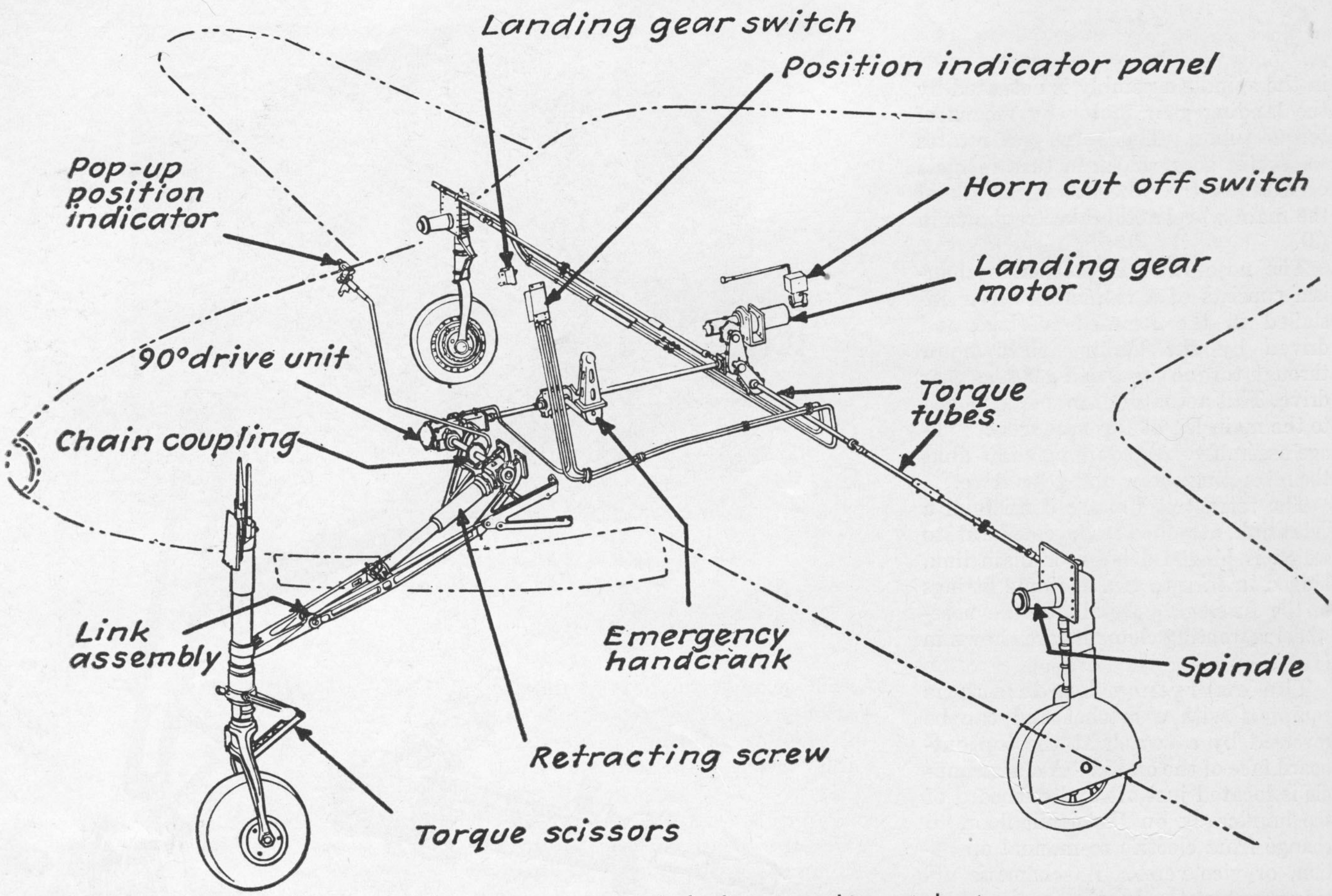


Fig. 5. Schematic arrangement of the landing gear and its control system.

PART 2. TWIN-ENGINE AIRCRAFT

Convair Liner

The Convair Liner is equipped with tricycle landing gear with dual wheels and Bendix air-oil shock absorbers.

The hydraulically operated main landing gear (1) swings forward into the engine nacelles. An auxiliary method of lowering the gear with compressed air is provided in case of hydraulic failure. Goodyear brakes also are hydraulically operated with an auxiliary air system available for emergencies. The size of the main gear tire is 34 by 9.9.

The nose gear features the keying of the dual wheels to the axle, causing the wheels to rotate together and making a very effective and simple shimmy damper.

Fig. 1. Front view of the right main landing gear of a Convair Liner. Retraction is forward into the nacelle.

Horten

In the little-known Horten 229 jet flying wing developed by the Nazis shortly before the end of the Second World War, the landing gear retracts hydraulically. The main wheels move inward while the nose gear retracts backward, the wheel making a 90-deg turn to lie flat in the well (1).

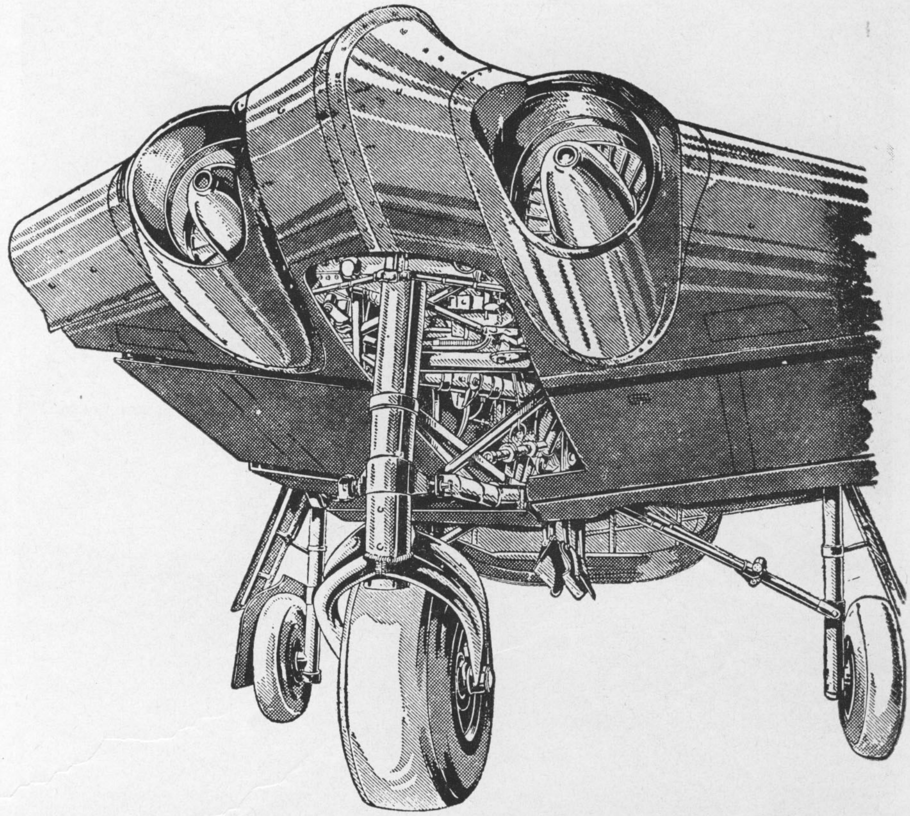


Fig. 1. Center section of the Horten 229 jet-propelled flying wing developed by the Germans shortly before their defeat. The landing gear retracts hydraulically, with the nose wheel making a 90-deg turn to lie flat in the well, and the main wheels moving inward. This craft was designed to be powered either by BMW-003 or Junkers Jumo-004 axial-flow gas-turbine jet engines.

Fairchild C-82 Packet

The C-82 is equipped with fully retractable landing gear consisting of a nonsteerable nose-wheel gear, main landing gear, emergency gravity extension system, door-operating mechanism, and warning and indicating systems.

No appreciable movement of the center of gravity of the plane is encountered (less than 1 per cent) as the landing gear units move from fully extended to fully retracted positions.

Nose gear (1) consists of an Aerol shock strut, single side strut and axle unit, hydraulic shimmy damper, 44-in. smooth-contour tire mounted on a magnesium wheel, upper truss, lower truss, retracting unit, and two retracting links.

The nose-wheel shock strut has a self-centering device which forces the wheel in a fore-and-aft direction as the load is removed. A fitting at the upper end of the strut is provided for attachment to the upper truss. Two cantilever arms are at the lower end for attachment of the lower structure. Provisions are made at the lower end of the piston for bolting the side strut and axle unit, and the shimmy damper is bolted to the cylinder.

The upper truss is V-shaped, and tubular units are equipped with double-lug forged fittings at the apex, and two single-lug fittings at the free ends. Double-lug fittings are welded at the mid-point of the tubes for bolting a forged-steel beam that holds the retracting links.

The lower truss consists of two outer tubes and an X brace. At both ends of the outer tubes, fittings are welded to form the upper and lower joints, and also to provide lugs for bolting the X brace.

The retracting mechanism consists of a ball-bearing screw-and-nut actuator, side mounting frames, double sprocket and chain train, torque shaft, and two retracting arms. The screw-and-nut actuator converts rotational motion at high speed to linear motion at low speed. A motor drives a planetary reduction gear train which turns the screw to cause linear movement of the nut.

A solenoid nut is incorporated to engage the motor instantly with the gear train upon application of the current, or to disengage it when the current is shut off. The clutch has a brake which automatically retards the gear train when the clutch is disengaged, to prevent the landing gear from continuing to move when the current is discontinued by the pilot or limit switches.

The nut is gimbaled to driving arms on two upper sprockets keyed to a spindle with ends supported in ball-bearing housings in the center of the side frames. The upper ends of the

Fig. 1. Nose gear: (1) axle unit; (2) side strut; (3) shock strut; (4) cantilever arm; (5) scissor; (6) front door (closed after gear is extended); (7) rear doors.

side frames are bolted to supporting fittings on the forward part of the fuselage, while the lower ends support a torque shaft on which are mounted two sprockets and two retracting arms. The lower sprockets are located in the plane of the upper sprockets, and retracting arms are in the plane of the retracting link. The torque shaft is supported at its ends by bearings located in fittings at the vertical fore-and-aft fuselage beams; in turn it supports the lower truss and a brace strut which ties the upper truss upper support fittings and the lower truss upper support.

Nose gear kinematic linkage—a parallelogram in form, with sides consisting of shock strut, upper truss, lower truss, and brace strut—permits the wheel and shock strut to move vertically during retraction. Retraction is accomplished by movement of the nut which causes rotation of the upper sprockets, whose motion is transmitted through chains to the lower sprockets to turn the torque shaft and retracting arms. The latter push the retracting links and cause the upper truss to rotate about its upper supports, thus lifting the shock strut and wheel into a retracted position. Upward movement of shock strut rotates the lower truss about the torque shaft, which guides the motion of the shock strut.

For nose gear gravity extension, the actuator is provided with a quick-release mechanism which disengages the screw from the gear train and allows the screw to rotate freely, the nut being forced down under the weight of the gear. To control the speed of drop, an energy-absorber unit is provided—basically a hydraulic actuator—which dissipates energy by passing fluid from one side of the piston to the other, through an orifice. Fluting the inside of the lower end of the cylinder increases the orifice area, and when the piston reaches these flutes, the increased area accelerates the flow of the fluid to speed the drop sufficiently to permit the down-locks to snap in place.

The main gear, extending about 12½ ft from the upper support point to the bottom of the wheel, is comprised of two shock struts, upper and lower main trusses, upper and lower drag struts, interconnecting transverse beam, and horizontal link bar tying the main upper truss to the upper drag struts (2). One end of each retracting link is mounted on the bolt which fastens the horizontal link bar to the upper drag trusses; the other end is bolted to two retracting arms fixed to a torque shaft which supports the retracting mechanism and its supporting side frames (3). The ends of the shaft are mounted in bearings housed in the nacelle steel structure.

The upper main truss is made of two swaged tubes with forged hinge fittings welded to the upper ends and forged knee fittings welded to the lower ends.

The upper ends of an X brace space the swaged tubes 43 in. at the top, while the lower ends of the brace and a spreader tube space the swaged tubes 30 in. at the bottom. Provision also is made on the swaged tubes for attaching the ends of the link bars.

The lower main truss has two swaged tubes with welded, forged knee fittings at the top and opened at the bottom to receive the shock struts. Tubes are held 30 in. apart by an X brace bolted to fittings on the sides of the tubes.

The upper drag struts, two king posts with apex on the bottom, have fittings welded to the lower ends and the apex, to attach to the lower drag struts at the end, and to the retracting link and horizontal bar at the apex. The main tube is made to extend at the upper end to the transverse beam, an oval-shaped tube with tapered ends on which are welded two sockets for receiving the upper drag trusses, two hinge fittings for mounting the beam to the nacelle structure, and two lug-type fittings for supporting the side frames of the retracting mechanism.

The lower drag struts are tubes with forged ends and separated by K bracing to space them 30 in. apart.

On each shock-strut cylinder are welded two double-lugged fittings: one on top to receive the lower drag strut, and one on the bottom on which

is bolted a jacking link. On the rear side, opposite these fittings, is welded a jacking fitting of AF standard dimensions. A forging at the lower end of the piston straddles the axle and is provided with two attaching bolts.

On the front face of the forging, a small hook is used to engage the jacking link to facilitate the servicing and installation of the wheel. When the jacking link (on the cylinder) is swung down over the hook (on the piston), the two attaching bolts are removed, and the plane is jacked at the jacking points on the cylinder. As the plane rises, the piston extends (because of the weight of the wheel) until the jacking link contacts the hook, and the piston then moves up with the cylinder and away from the axle to permit the 56-in. wheel to be rolled from under the shock-strut fittings.

The retracting links and arms and retracting unit consisting of actuator, chains, sprockets, and torque shaft, are similar to those used on the nose gear, but larger. Two energy-absorber units are used on each main gear and, except for length, are also similar to nose gear installation.

During retraction, the retracting link forces the upper drag strut to rotate about the hinge points of the transverse beam, and the horizontal tie bar forces the upper main truss to rotate to the rear about the upper hinge fittings. Rotation of upper truss breaks the knee joint between the upper and lower main truss and carries the upper end of the main lower truss to the rear and upward.

At the same time, the rotation of the upper drag strut carries the lower drag strut and the lower end of the main lower truss forward.

Control of the landing gear is from the cockpit by either pilot or copilot by a dual handle. Freed of the locating slot, the handle is pulled to a vertical position to retract the gear, thus turning a shaft on which are mounted two pulleys. Cables anchored to the pulleys actuate a series of levers and cams which cause the down-locks to open, freeing the retracting arm and permitting the torque shaft to be rotated.

The handle, on reaching the vertical position, is pushed to the side into a positioning slot and actuates switches in the landing gear motor circuits to cause retraction of the gear. The retracting arm, on reaching the maximum position, trips a switch to stop the actuator motor.

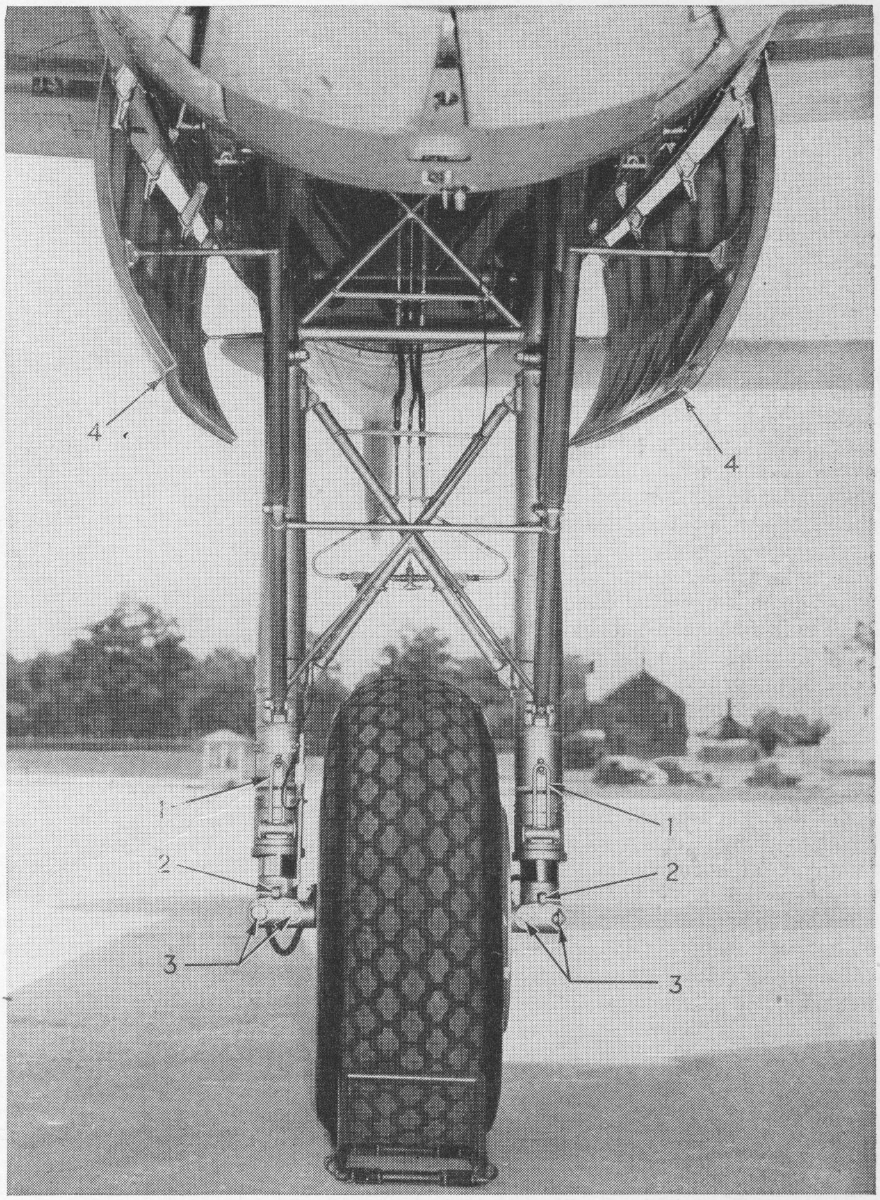


Fig. 2. Front view of the main landing gear, looking aft, showing double struts. To facilitate removal and servicing of wheel, link (1) on the cylinder is swung down to engage hook (2) on the piston, attaching bolts (3) are removed, and when the plane is lifted at the jack point (on the cylinder behind the link hinge) link raises the piston away from the axle to permit the wheel to be rolled from under the strut. Doors (4) remain open after the gear is extended.

To extend the gear, the operating handle is moved forward and down to the normal DOWN position. Engagement in the position slot actuates a switch in the circuit, and the gear moves to the extended position. As the spring-loaded dogs engage the latches on the retracting arm, they actuate a switch which cuts the current.

The gear may be extended by gravity, in the event of power failure, by pushing the control lever forward and down, past the normal down position to the emergency DOWN position.

A safety switch, installed on each landing gear unit to prevent accidental retraction of the gear when the plane is on the ground, closes the motor

circuit only when the oleo struts are extended, as in take-off, with load removed from the strut.

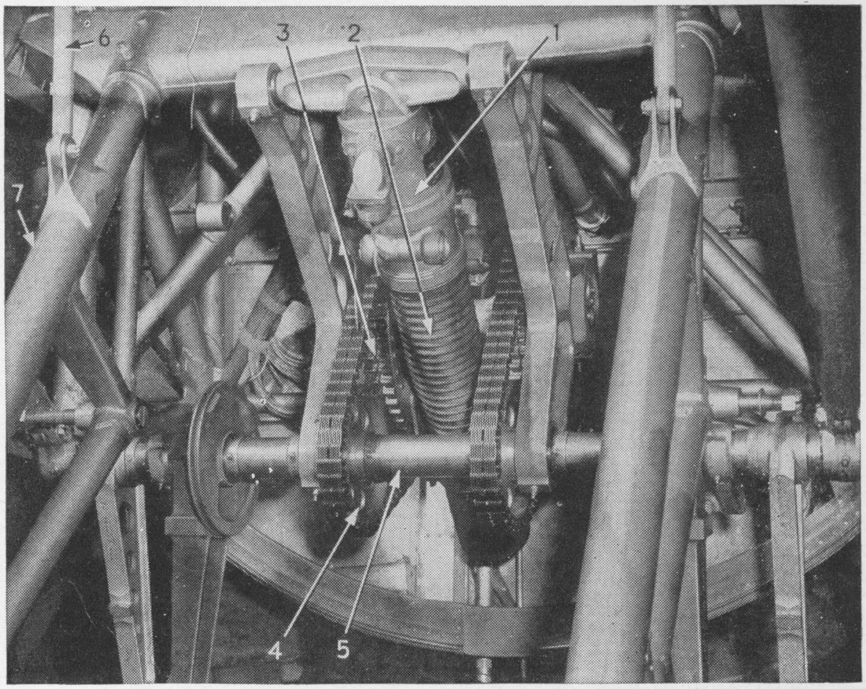


Fig. 3. Landing gear retracting mechanism: (1) actuator; (2) boot over actuating screw; (3) upper sprocket; (4) lower sprocket; (5) torque shaft; (6) hydraulic snubber piston; (7) upper drag strut.

As an additional precaution, a ground lock consisting of a steel pin (with red streamer for visual attraction) is inserted into the locking links to prevent unlatching of the locking dogs. With locking dogs engaged, the gear cannot be retracted.

Two lights in the cockpit indicate gear position. A green light indicates that it is down and locked, whereas a red light shows that it is neither fully retracted nor fully extended and locked. No lights show when all gear units are fully retracted, but to avoid landing with retracted gear, a warning horn sounds and a red light shows when the throttles are pulled back.

The forward section of the nose-wheel doors is operated directly with a push-pull rod actuated by the gear retracting link. As the gear extends, the front door opens fully to allow the wheel to pass and is again closed when the gear has reached its fully extended position. The rear doors remain open after the gear extends. They are operated by push-pull rods actuated by two arms (on a torque shaft mounted on housings on the vertical beam in the nose section) in turn operated by push-pull rods actuated by movement of the lower nose gear truss. Side frames of the truss have welded hinge brackets which provide attachment for the operating rod.

Because of their great length, the nacelle doors are actuated at front and rear by a parallel system of torque shafts and arms interconnected by cables. The main operating arms are hinged on the main landing gear torque shaft and are held in the door-open position by torsion springs on the rear torque shaft. Operating arms are combination arm and pulley arrangements. The door-actuating push-pull rods are fastened to the ends of the arms, and cables anchored to the pulleys run to the top of the landing gear well over two sets of guide pulleys to similar pulleys of arm and pulley arrangement hinged on a torque shaft at rear of the well. At the end of these arms, door-operating push-pull rods are hinged.

After the main landing gear torque shaft has moved through two-thirds of its full travel, it picks up the actuating arms and carries them with it as it moves to the fully retracted position. The nacelle doors remain opened when the landing gear is fully extended.

Pressure for operation of wheel brakes is obtained from 1,000-psi hydraulic system. A motor-driven gear-type pump maintains pressure in two accumulators separated by check valves. One accumulator supplies pressure to the power-brake valves connected to the outboard brake units. This, in effect, provides two independent systems for operation of the brakes, and failure of one of the systems results in the loss of only half of the braking capacity. In event of power failure, the accumulators, when fully charged, are of sufficient capacity to bring the plane safely to a stop.

The system pressure is regulated by a Starbird type of pressure switch with power contacts adjusted to close at 980 psi and open at 1,160 psi. Warning light contacts, adjusted to close at pressures below 800 psi, energize indicator lamps located on the instrument panel, to warn the pilot of failure of the pump to maintain normal system pressure. Pressure gauges attached to the air side of the accumulators and mounted on the instrument panel indicate preload air pressure when the accumulators are discharged and hydraulic pressure when they are charged.

Curtiss C-46 Commando

The main units of the C-46 landing gear (1), having a tread of 25 ft 11 in., consist of single Cleveland Pneumatic Tool oleo-pneumatic shock absorbers, braced fore and aft by tubular drag struts which are aligned by forged upper and lower drag links. Sidewise bracing is by similar tubes, and all tubular units incorporate forged terminal fittings.

The wheels are retracted through hydraulic operation, taking less than 10 sec, as follows: The DOWN latch at the top of the shock strut is first released, and the upper end of the strut moves backward while the wheel moves up

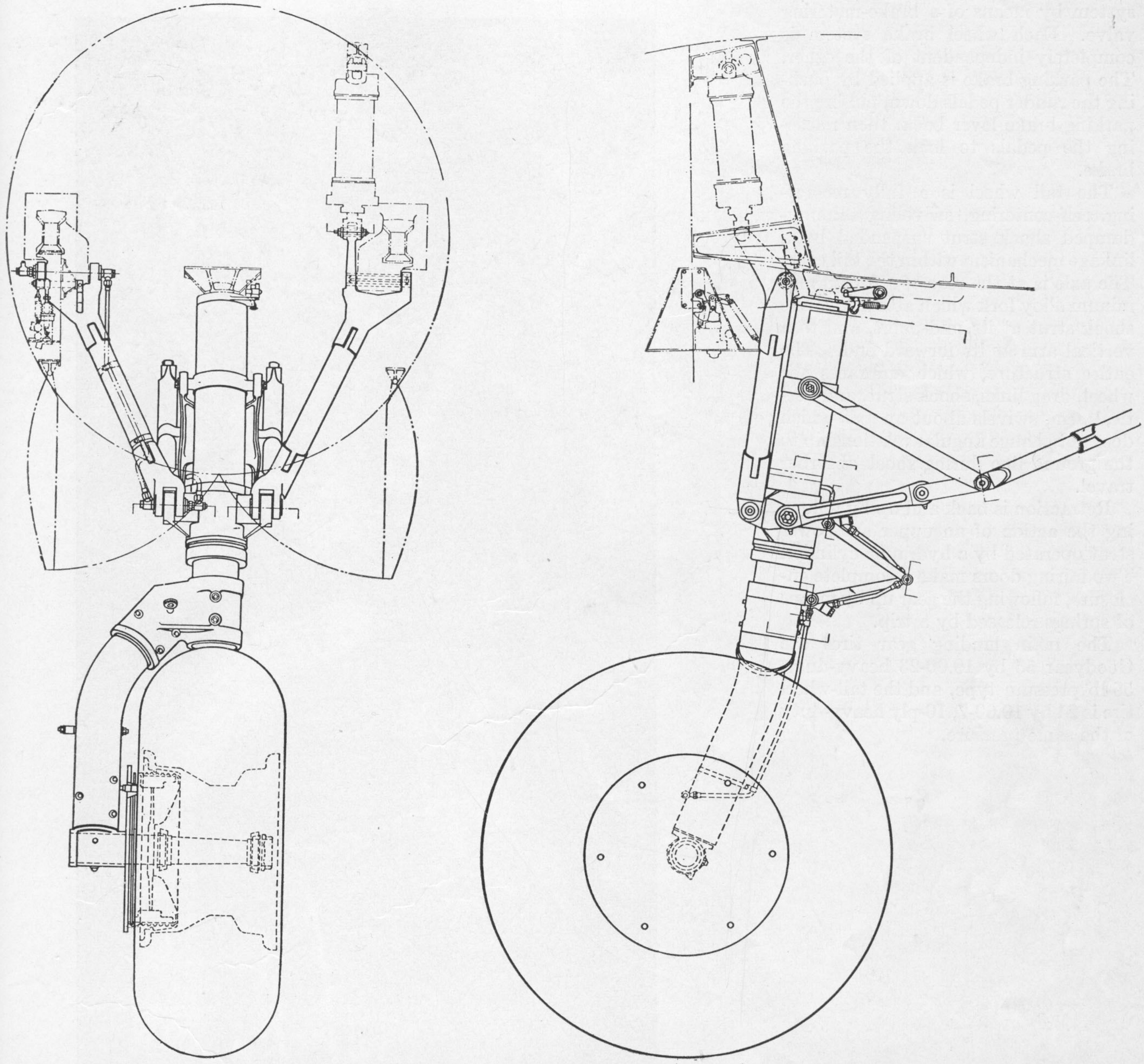


Fig. 1. Although the C-46 is consistently flown at twice the design gross weight of the prototype, the landing gear is simple in design. Hydraulic retracting action, requiring less than 10 sec, is through a vertical cylinder attached at the top to the front spar and nacelle bulkhead and at the bottom to a bell crank comprising part of the outboard side brace strut. A hydraulically operated sequence valve operates two fairing doors.

and forward, being guided into its position in the nacelle by the rear drag struts, the drag links, and the side brace struts. Retracting action is imparted by the extension of a vertically mounted hydraulic cylinder fastened at the top to a fitting attached to the front spar and nacelle bulkhead, and at bottom to a bell crank which is part of the outboard side brace strut (2, 3).

When fully retracted, the gear is locked in UP position by a latch. Two fairing doors, hydraulically operated through a sequence valve, follow the wheel up to enclose it completely in retracted position.

Emergency lowering of the gear can be accomplished by an auxiliary manual extension system. A warning horn in the cockpit blows if either throttle is less than one-quarter open when either wheel is not locked in full DOWN position. The landing gear has been built so that the plane is not at a sharp angle in a three-point position, for the main cargo compartment floor is but 9.5 deg from horizontal, a feature designed into the plane to make cargo loading and unloading easier. Either wheel or three-point landings can be made with equal facility, depending on the pilot's preference.

The main gear wheels are of magnesium alloy, with double expander-type brakes operated by conventional rudder toe pedals from the main hydraulic

system by means of a brake-metering valve. Each wheel brake system is completely independent of the other. The parking brake is applied by pushing the rudder pedals down, pulling the parking brake lever back, then releasing the pedals to lock the parking brake.

The tail wheel is a fully retracting, self-centering, swiveling shimmy-damped shock strut suspended by a linkage mechanism within the tail cone. The axle is at the rear of a forged aluminum alloy fork which attaches to the shock strut at its mid-point, and to a vertical arm at its forward end. The entire structure, which embraces the wheel, drag links, shock strut, and vertical arm, swivels about an axis which does not change angular relationship to the ground line during shock-absorber travel.

Retraction is back and up by following the action of an upper and lower strut operated by a hydraulic cylinder. Two fairing doors make a complete enclosure, following the gear up by means of springs released by a trip.

The main landing gear tires are Goodyear 55 by 19.00-23 heavy-duty, 55-lb pressure type, and the tail-wheel tire is 24 by 10.00-7, 10-ply heavy-duty of the same pressure.

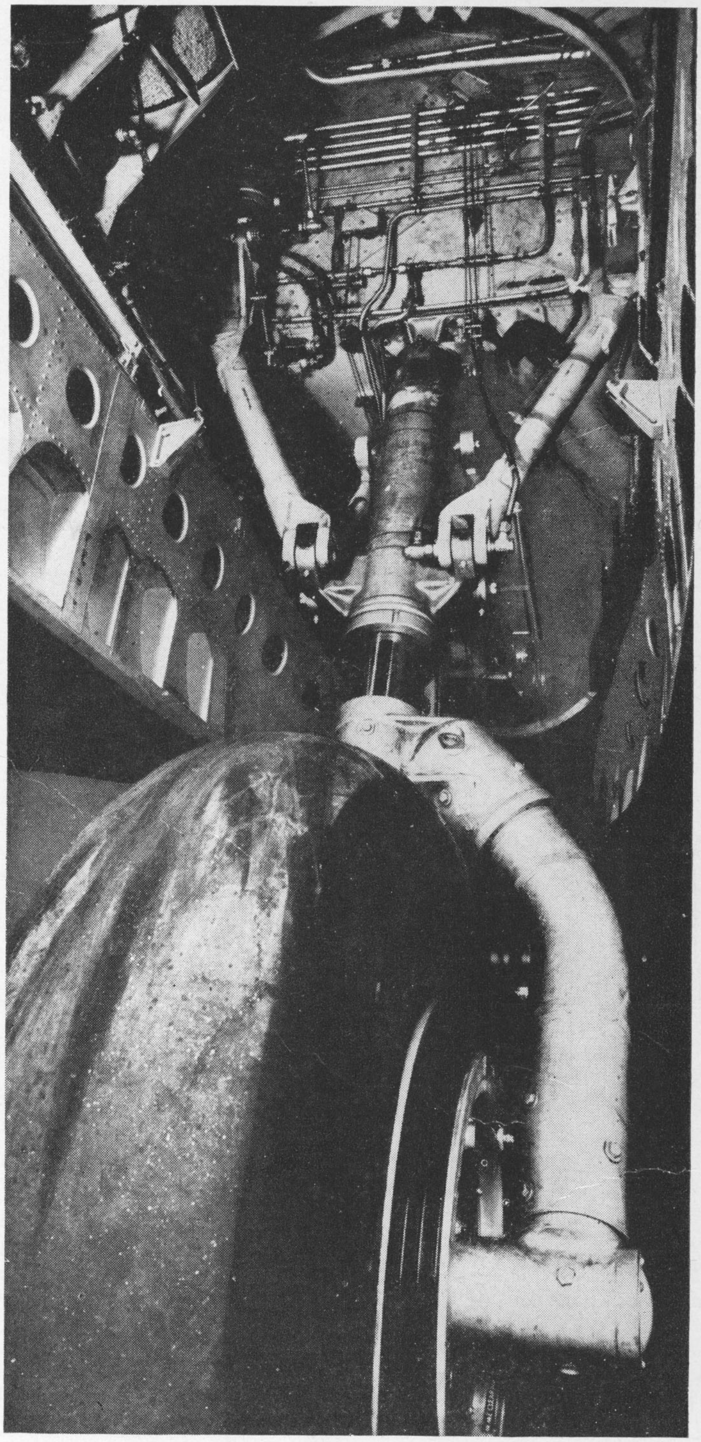


Fig. 2. A head-on view of the nacelle shows the hydraulic retracting cylinder and bell crank at the upper left, forming part of the outboard side brace strut. Ahead of the side brace struts are smaller hydraulic units, with a sequence valve, for closing the fairing doors to enclose the retracted wheel.

(a)

(b)

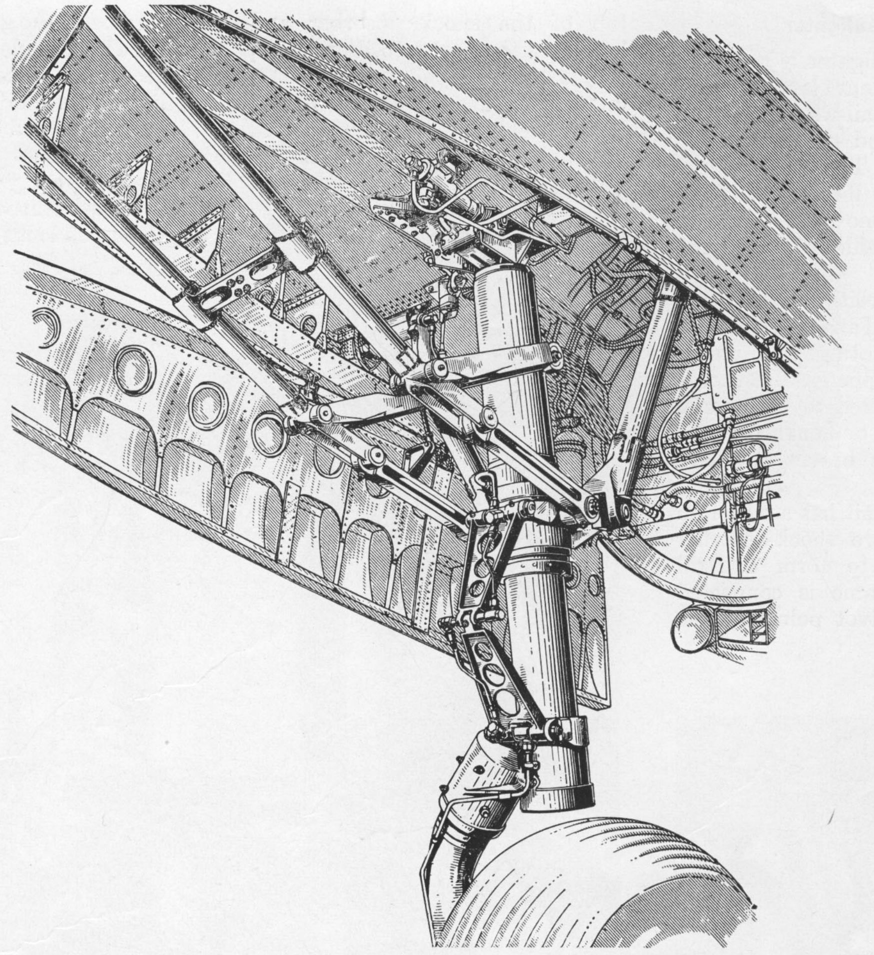


Fig. 3. Main landing gear in extended position (*a*) showing the side brace struts, H-frame fore-and-aft bracing, and latching lock atop the air-oil shock absorbing unit. During retraction, the top of the shock strut moves aft while the wheel moves up and forward to position, as shown in the three-quarter front view (*b*).

Bristol Beaufighter

The Bristol Beaufighter is provided with two independent landing gear main units and a tail-wheel unit, all simultaneously raised or lowered by hydraulic power. The main gear swings back and up into the nacelles, while the tail wheel moves forward and up into the underside of the stern frame.

Three electric position indicators, one for each unit, and an electric buzzer comprise the indicating and warning devices. Oleo-pneumatic shock-absorber legs are fitted to both main gear (either Vickers or Lockheed) and tail wheel. Dunlop brakes are used on the main gear.

Each main gear unit has a wheel on an axle between two shock-absorber units cross-braced to form a rigid frame (1). The frame is connected to the nacelle at pivot points at the top of the shock absorber and is braced in the DOWN position by a pair of knee-jointed radius rods (2), the upper portions of which are fixed to a transverse torque shaft supported in bearings on the rear tubes of the nacelle structure.

When the gear is retracted (3), nacelle doors, shut by shock-absorber cords, fair the gap at the bottom of the nacelle, completely housing the main gear and wheel. A catch, operated by levers and Teleflex controls, is interconnected to the hydraulic selector lever. When the main gear is retracted, and the hydraulic selector lever is returned to the OFF position, the catch locks the doors.

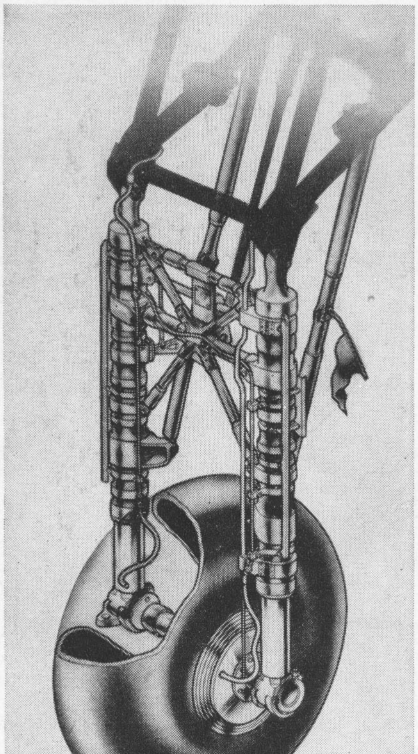


Fig. 1. Light loads are cushioned by air, heavier loads by hydraulic loadings. Brakes are pneumatically operated. A warning flag indicates when the safety lock is on, preventing the gear from being raised.

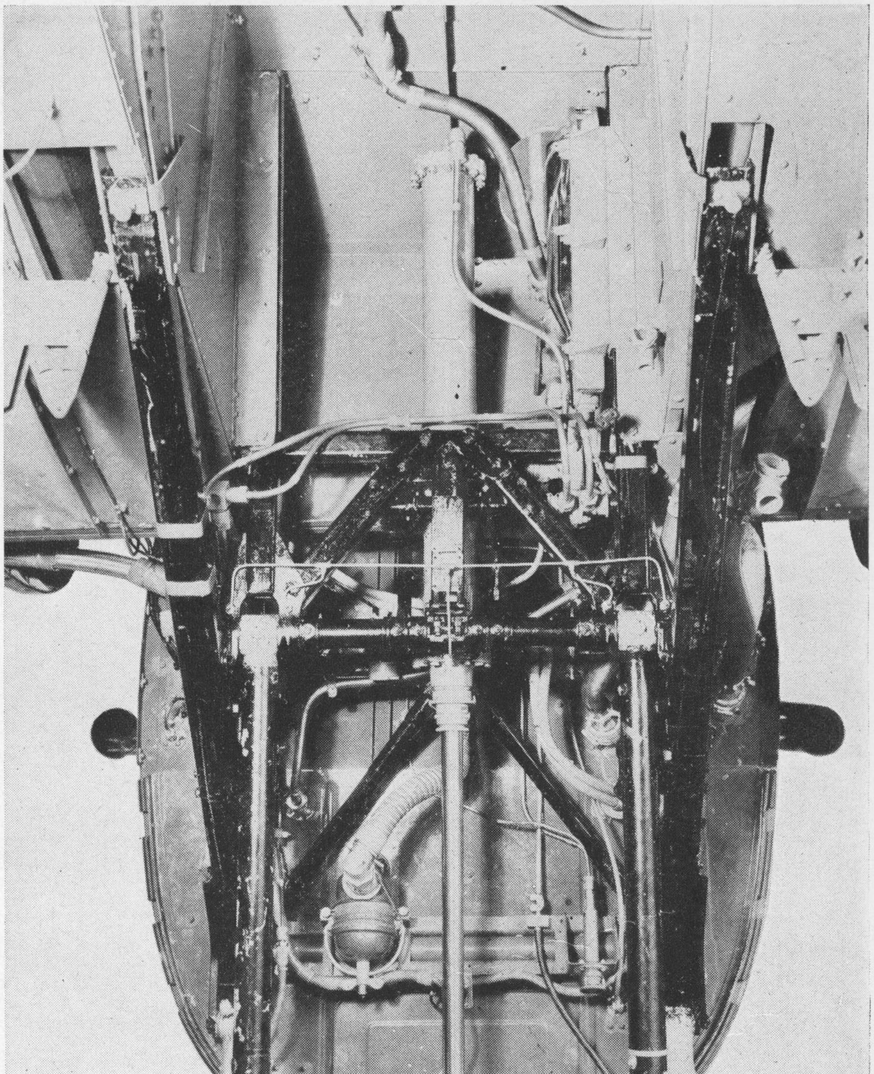


Fig. 2. A landing gear hydraulic cylinder as seen from the rear, when looking forward and upward, with the gear extended. Jointed radius rods, which hold the gear in DOWN position, are hinged onto a cross member in the center. The carburetor and induction-system priming pumps, accessible only when the gear is lowered, are seen inside the cross members.

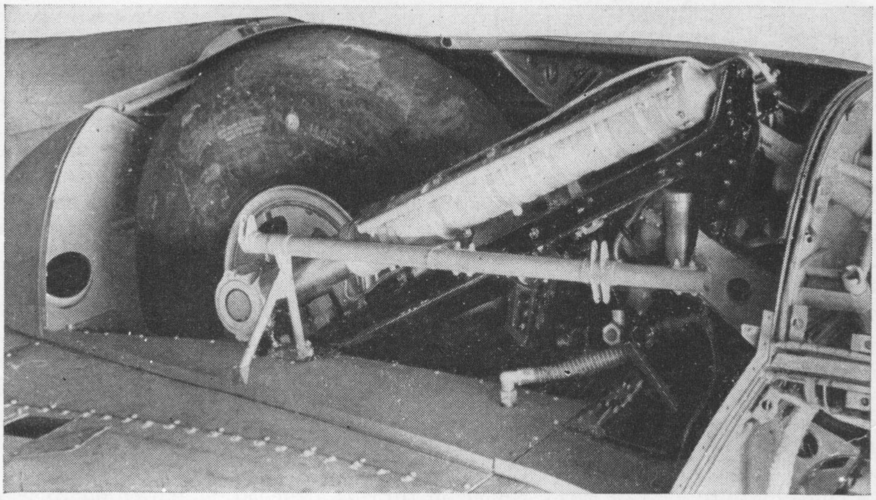


Fig. 3. Retracted landing gear. The large cylinder, one each side of the wheel, is oleo strut shock absorber. A heavy triangular frame attaches the gear to the front spar and the wing rib. One fairing panel has been removed to show the mechanism.

Martin B-26

As the main gear of the Martin B-26 Marauder is moved up and forward, the fairing is pulled into place by four rods with universal joints. The two lower ones are connected to the oleo shock strut just above the torque scissors, while the top ones are connected to the top of the shock strut (1).

The fairing is a built-up double-skin structure designed to withstand rough usage.

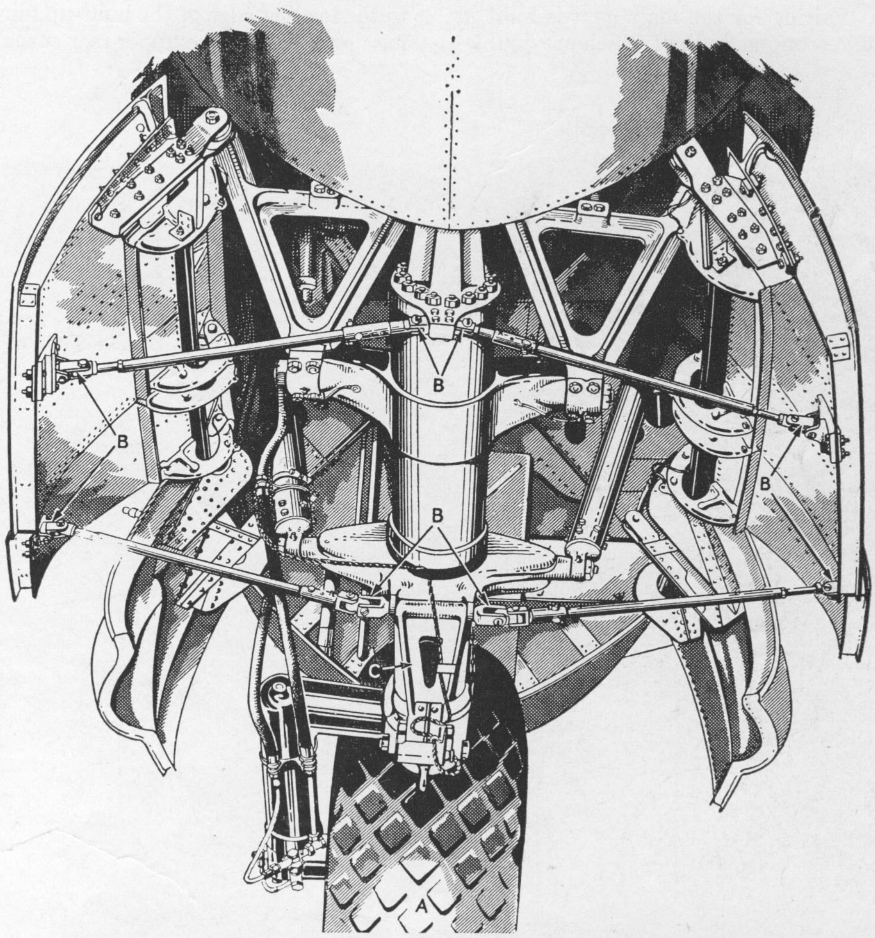


Fig. 1. The aft section of the Martin B-26 main landing gear fairing, seen here from the rear, is pulled into place as wheel *A* is moved up and forward to its position behind the engine by four rods with universal joints, seen at *B*, the two lower rods being connected to the oleo shock strut just above torque scissors *C*; the two top rods at the top of the shock strut. Note that the fairing is built-up double-skin structure designed to withstand hard field use.

Messerschmitt Me-262

Oleo struts for the Me-262's main wheels of the hydraulically retractable tricycle landing gear are hinged in a built-up steel box structure (1) on the end of spanwise spars extending 30 in. from the root rib midway between the main and auxiliary spars (2).

The forged oleo strut is 26 in. long, $5\frac{1}{3}$ in. in diameter, and has conventional torque scissors on the aft side designed for a 20-in. piston travel. In preparing the craft for flight tests, it was found that the main wheels had considerable lateral play, but when the normal 1,200-lb pressure was built up, the wobble disappeared.

The retracting jack is bolt-hinged to a steel fitting bolted to the root rib at the end of the front spar of the landing gear torque box, while the piston is attached to the front of the oleo strut by a ball-and-socket joint.

Fairing for the main gear is built in two sections, both of which are double-skinned, grid-type structures with the top section hinged to the torque box end, and the lower bolted to a bracket welded to the oleo piston just above the axle (4).

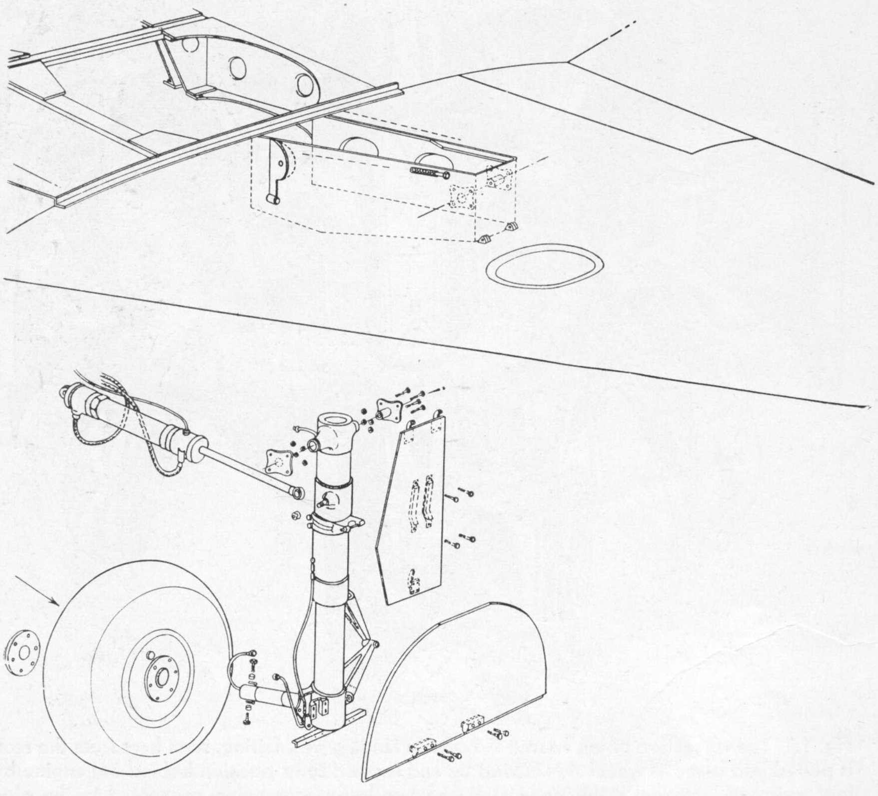
In operation, the main wheels swing up and into the bottom of the fuselage, with the right strut operating an actuating valve at the end of its arc. This valve in turn closes fairing doors which are hinged at the fuselage center line and serve as the landing gear uplock (3).

To accomplish this, a hydraulic cylinder is attached parallel to the aft face of the main spar just to the left of the fuselage center line (5). Its piston is connected to a welded-steel box-type bell crank which, in turn, is attached by a universal joint to another box bell crank set between two stamped, flanged vertical plates set along the center line. At the lower corner of this bell crank are universal joint tie rods connected to the leading edge of the built-up fairing doors, and at the upper rear corner is a flat steel tie rod connected to a triangular-shaped built-up bell crank attached to similar tie rods on the trailing edge of the fairing doors.

Thus when the oleo strut hits the actuating valve, the piston moves to the right, forcing the tie-rod-connected bell cranks to snap the doors closed under the wheels, with the 90-deg change in direction between the units serving as the locking mechanism after the hydraulic pressure on the piston are relieved.

The nose wheel (6) retracts aft and up into a well below the armament compartment; the wheel, near the end of the retracting arc, striking a transverse tube which pulls the double-skin fairing door closed (7). Spring-loaded pins moving into the piston serve as up-and-down locks.

The nose gear retracts and extends after the main wheels have been locked either up or down.



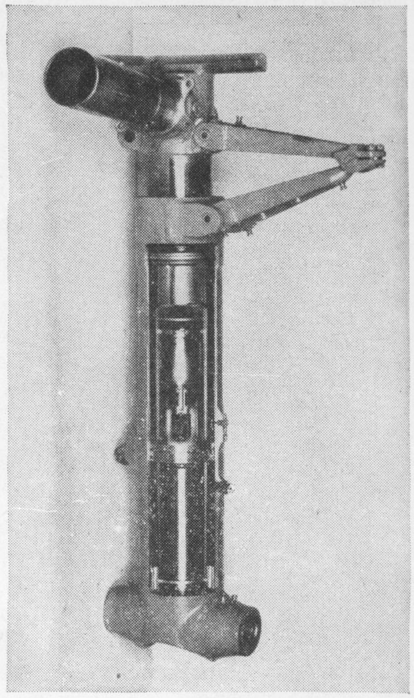


Fig. 1. Exploded view of the main landing gear and a phantom sketch of the wing showing the position of the landing gear torque box and wheel well (1*a*). The cutaway (1*b*) shows the main landing gear oleo strut with hinge bearings and wheel axle welded in place.

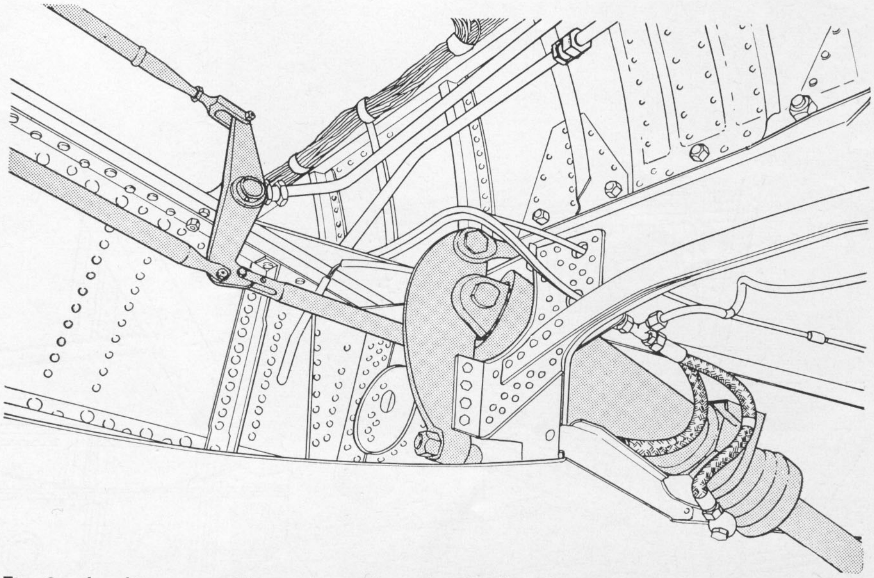


Fig. 2. Looking up and forward into the right wheel well at the fitting for the landing gear retracting cylinder, which is attached to the root rib. At the upper left, attached to the main spar top boom, is the aileron bell crank showing the difference in size in the push-pull rod from the control stick (top) and those extending to the ailerons (bottom). Above the retracting cylinder fitting can be seen self-locking nuts, attaching the fuselage skin to the flange on the upper wing structure.

Fig. 3. Looking up and aft into the main gear wheel well. Center-line fairing doors, which serve as landing gear up-lock, and the construction of the auxiliary spar will be noted. Just above this spar can be seen the bottom part of a cylindrically shaped cockpit liner, a unit designed for pressurization but unused in this way. The opening in front of the main spar takes a 53-gal reserve fuel tank.

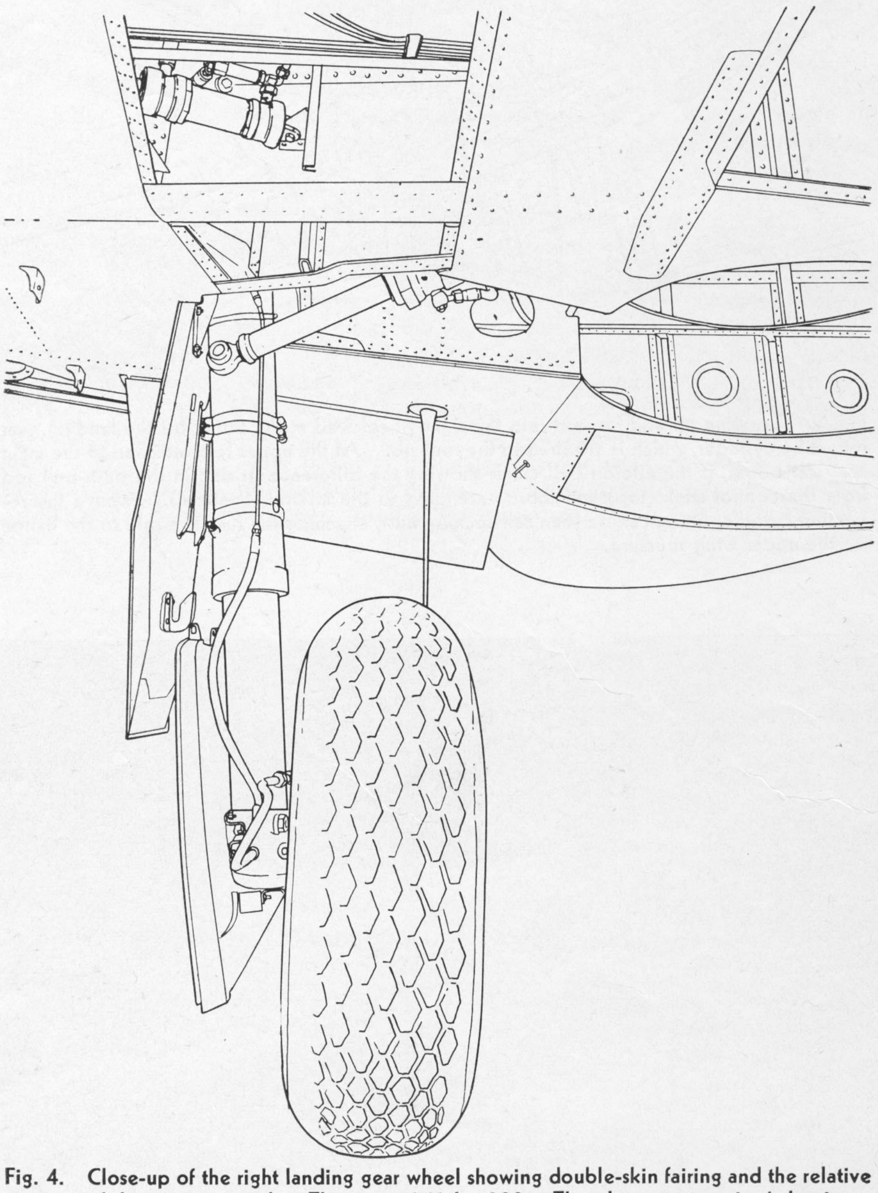
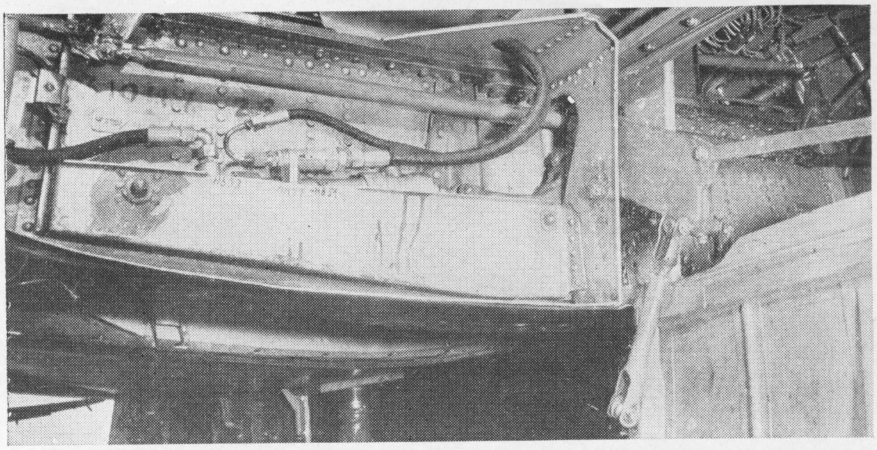


Fig. 4. Close-up of the right landing gear wheel showing double-skin fairing and the relative position of the retracting jack. The tire is 840 by 300. The oleo strut toes in 4 deg in an extended position. The flap-actuating piston can be seen on the front face of the main spar directly ahead of the oleo. The lower wing surface (here removed) is attached by flush screws.



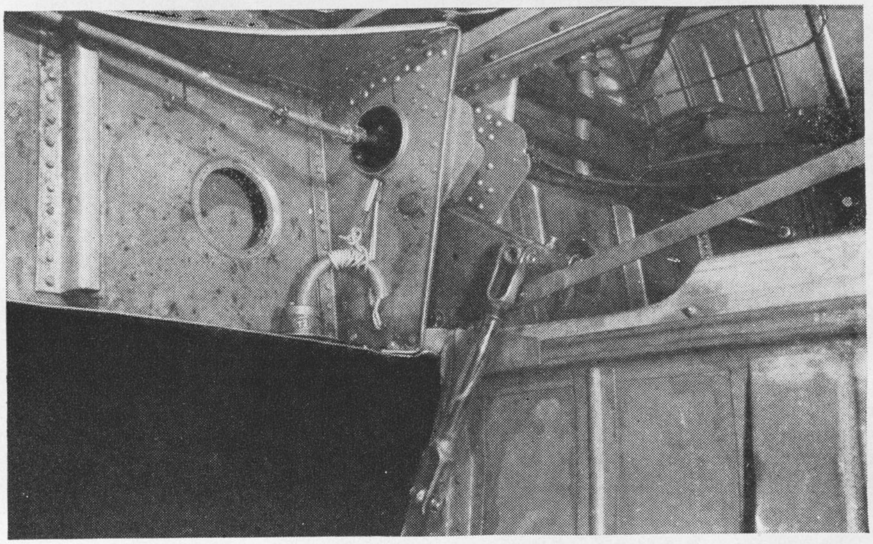
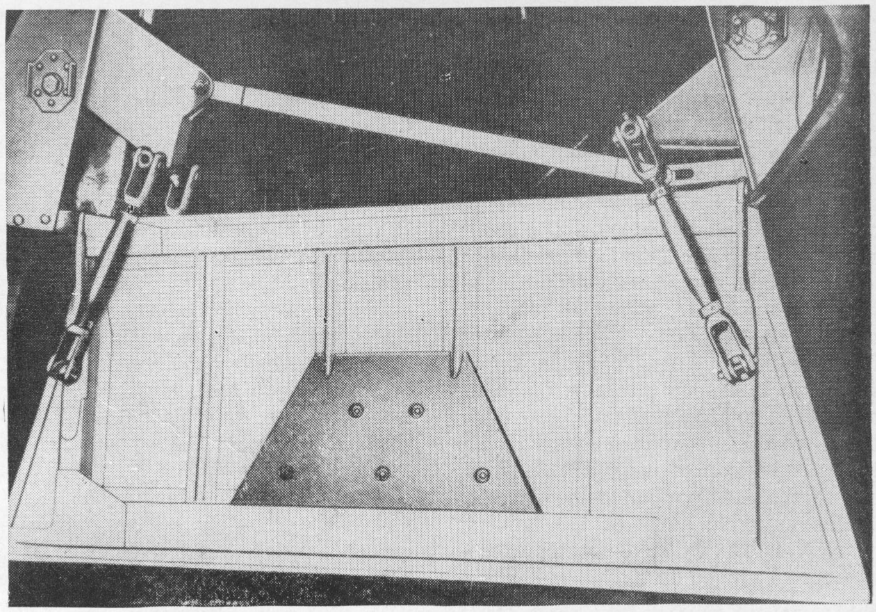


Fig. 5. The top photograph, made from the left main wheel well, shows the fairing door operating a cylinder fitting on the aft face of the main spar at the left center, with universal-joint connection to box-type bell crank, which is, in turn, universally connected to fairing doors, a corner of which is shown at the lower right. A flat tie rod on the upper corner of the bell crank is connected to the crank, which distributes power to the aft end of the doors, details of which are shown in the center photograph. The connecting linkage here is bolted to a box-type structure attached to the front face of the auxiliary spar. The lower photograph is of a German perspective sketch, showing how the unit was designed.



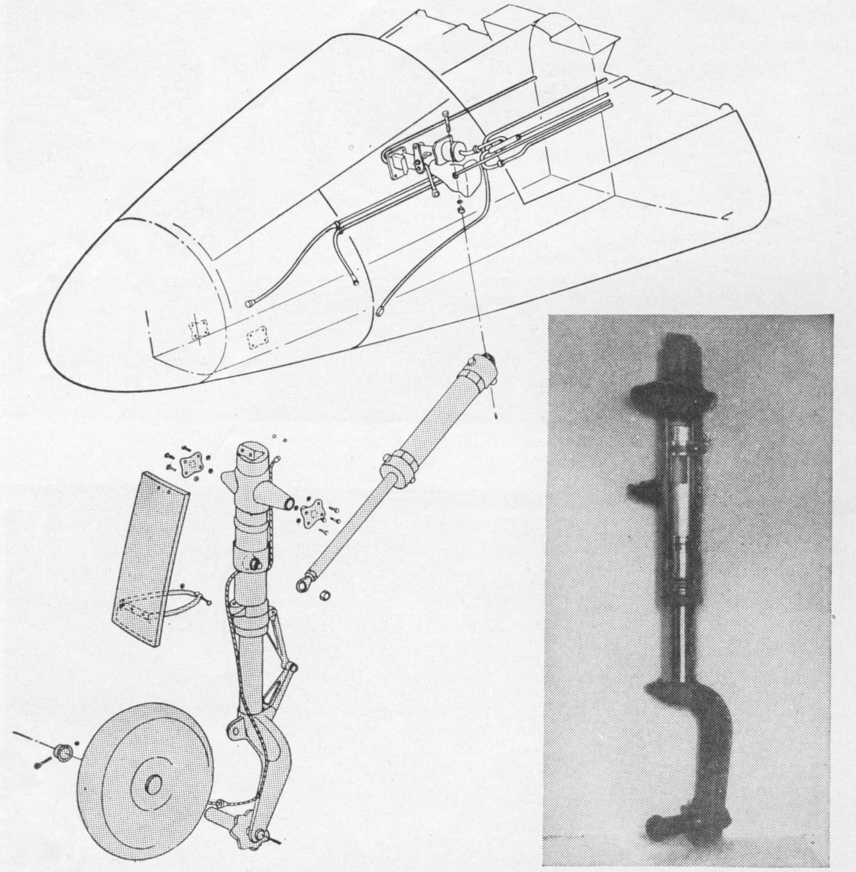


Fig. 6. Phantom view of the installation of the nose landing wheel, which is depicted in the exploded view. The inset is a cutaway of the nose-wheel strut. Note that the original plans called for conventional torque scissors; however, late model ME-262's had built-in shimmy dampers.

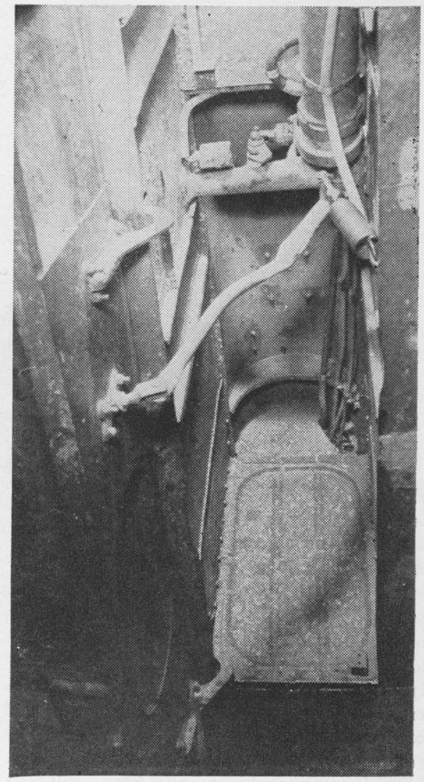


Fig. 7. Looking aft and up into the nose wheel well at the retracting cylinder attachment. As the nose wheel retracts, it strikes a tubular linkage to pull and lock the fairing door closed.

De Havilland Mosquito

The Mosquito's landing gear consists of two interchangeable units attached by tubular structures to the wing immediately behind the engines (1). Two brackets on the front of the forward wing spar serve as pickup points for both engine mounting and landing gear. These brackets are bolted to companion angles that tie the front spar and wing ribs 3 and 4 together.

The landing gear supports extend downward behind the fire wall to a horizontal tube that serves as a hinge point for the landing gear. This upper structure is braced laterally by diagonal tubes and longitudinally by heavy tubes which terminate in brackets on the rear portion of wing ribs 3 and 4 and form a fixed portion of the support.

The movable parts of the landing gear consist of oval steel-tube compression struts hinged on a fixed horizontal tube. At the bottom they are secured to the axle with forged-steel U straps. Legs are cross-braced by tubular members diagonally arranged and are held in place by radius rods that are attached to the rear of the legs and to the rear wing spar. A double-acting hydraulic jack raises or lowers the gear.

Each landing gear unit is provided with doors that close automatically as the unit is retracted into the wheel well (2). A latch mechanism on the right-hand radius rod holds the gear in UP position. The DOWN position is secured by a spring-loaded mechanical safety latch incorporated in the lower fitting on the hydraulic jack cylinder. It engages in a collar on the jack ram and is released only by hydraulic pressure on the safety valve when raising the landing gear.

The bottom sections of the right- and left-hand radius rods are joined together at their upper ends by a large tube and forged fittings. Since the hydraulic jack is attached only to the right-hand radius rod, the cross tube must carry the load due to lifting the left-hand radius rod.

A visual indicator in the cockpit shows when the gear and tail wheel (3) are locked in UP or DOWN position, and a warning horn sounds when the landing gear is not locked down and throttles are more than three-quarters closed.

Two micro switches on the landing gear operate visual indicators; the UP switch is located just above the UP latch bracket on the right wing rib and operates when the latch has engaged the up-lock; the down-switch is on the main gear jack cylinder. A Graviner gravity type is used.

A second switch is introduced in the circuit so that the gravity switch can be rendered operative when the wheels are down and inoperative when they are up. This is necessary to prevent the fire extinguisher from functioning during aerobatics.

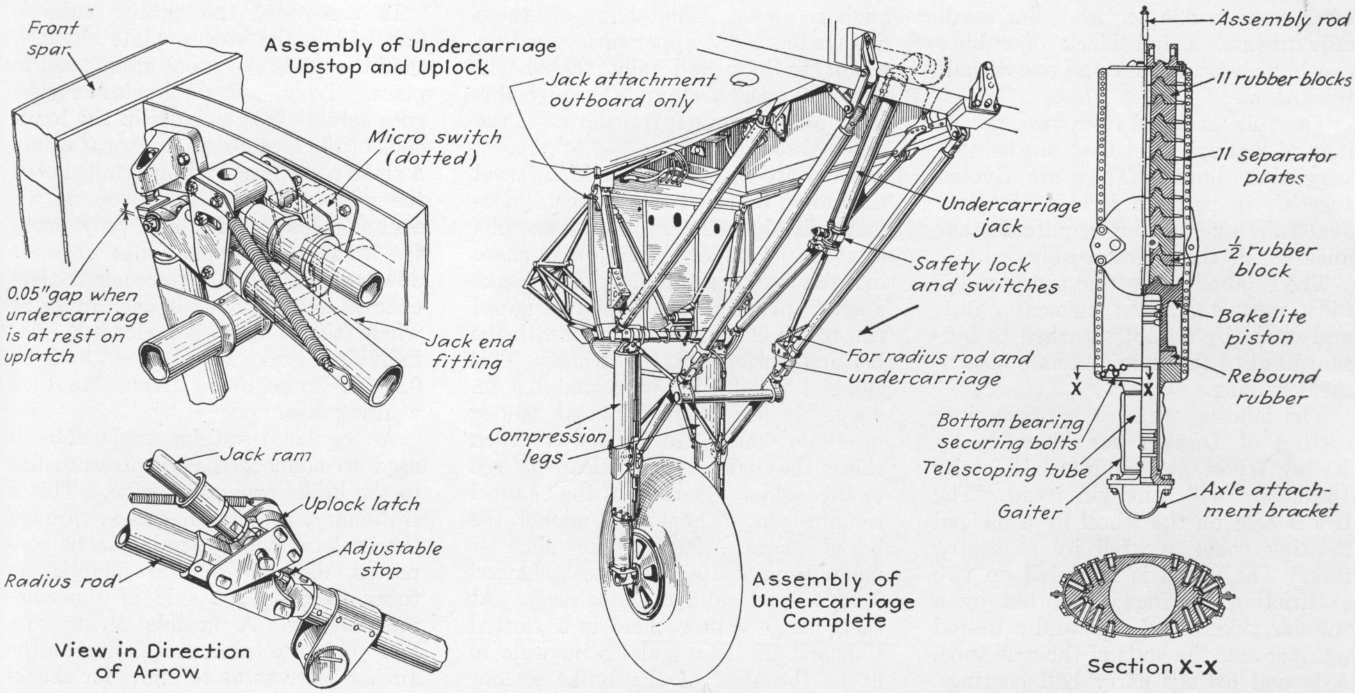


Fig. 1. The landing gear with details of the lock, hydraulic jack, and compression strut. A micro switch is attached to the side member of the frame.

Two shock-absorber struts are compression rubber type and are oval in section, made from 8-gauge steel stampings. The upper head carries a bracket that is hinged to the stationary landing gear frame. The lower or open end of the tube is closed by a fabric and bakelite-molded head which guides the tubular piston rod. An oval bakelite piston slides up and down inside the tube.

Eleven rubber compression blocks are nested between the head of the strut tube and piston. The blocks are smaller in section than the tube to allow for expansion. There are eleven blocks of full thickness and one of half thickness, all located above the piston; also one block beneath the piston to absorb rebound.

Each block is molded with two conical projections on the top and corresponding depressions in the bottom to keep the blocks and plates in alignment. The piston tube is attached to the bakelite piston by scrivets and threaded rods. Where the piston rod passes through the bakelite guide, the bore is lubricated with graphite. The bottom end of the piston tube carries a rectangular forged flange to which the wheel axle is attached by a forged-steel U-shaped strap and four bolts.

Since there is no hydraulic or pneumatic mechanism in the strut to leak, it can be made without recourse to micro finishes. No adjustment is required in service beyond renewal of the compression and rebound rubbers

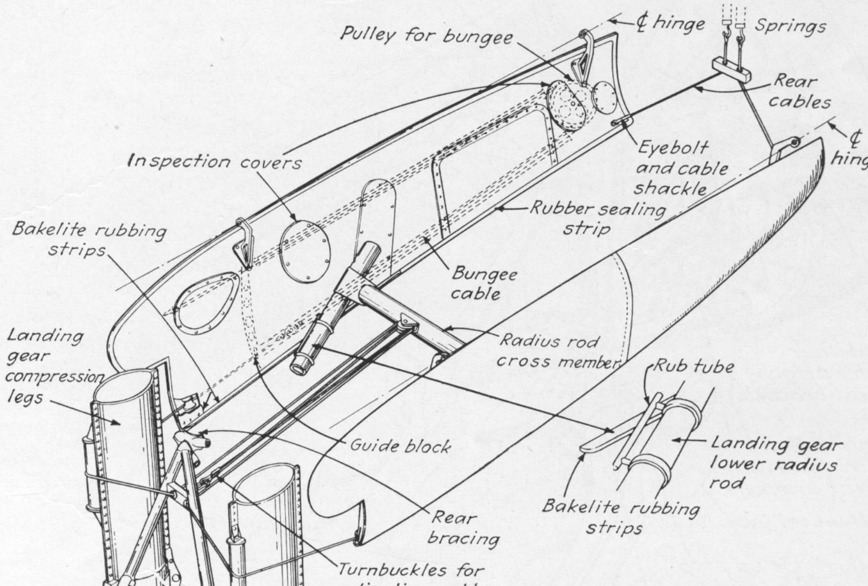


Fig 2. A bungee in the wheel doors provides force for closing them when the gear is raised. A cable attached to the radius rod cross member gives sufficient tension to the bungee, while rollers on the outside of the compression legs move the cable outward to cause the doors to open. Bakelite rubbing strips on the radius rods prevent wear on the members.

after considerable service. For small adjustments, a full block of rubber can be substituted for the one of half thickness.

The tube is made from two stampings of 8-gauge steel that are held to very close limits. They are riveted together in pairs to form a complete oval tube and do not require further finish inside the afterassembly.

The exposed end of the piston rod is fully protected from elements, dirt, and water by a boot attached to bottom head of the tube and axle attachment forging.

The landing wheel is a magnesium casting of Dunlop design, made by Kelsey Wheel, and mounts a 15.00- by 16-in. tire with antiskid tread. The tire is held on the wheel by a flanged locating collar secured by a locking ring. The wheel is mounted on two antifriction bearings supported by a tubular axle. End caps and a tie-rod retainer seal the ends of the axle tube. Axle end fittings carry ball bearings. They are flanged to attach the brake anchor plates. The hub of these fittings has a flat upper surface with a spigot to lock and pilot the shock-absorbed strut bottom. Through this the braking torque is transferred to the shock-absorber unit.

There are two 13- by 3.25-in. internal expanding brakes in each wheel, pneumatically operated by a rubber tube located just under the six brake shoes in each brake assembly. The brake anchor plate has a channel-shaped rim which extends inward beneath the braking surface of the wheel. This channel is 3.37 in. wide and 0.5 in. deep. It has 1.5-in. slots at 60-deg intervals which are located at each side of the channel and go clear through to the inside. The rim of the channel is unbroken. These slots anchor the brake shoes. Each brake shoe is made from a 16-gauge steel channel 3.25 in. wide and 0.37 in. deep. At each flange center there is a slotted tongue 1 in. deep and 1.5 in. wide to fit in the slots of the brake anchor plate (4).

In assembly, the rubber tube is first laid in the anchor plate channel, then the six brake shoes are slipped in place. To hold them, a retainer yoke goes across between slots in the lower ends of the brake-shoe anchor tongues. A small coil spring is slipped in between the yoke and the underside of the anchor plate. This not only locks the brake shoe in place but draws it down tightly against the anchor plate channel and prevents it from dragging when the brake is released. The individual brake shoes have a 3.25- by 0.25-in. brake lining riveted to their working face.

A regular tire-tube angle stem is used to connect the air-pressure line to the brake expanding tube. This is stationary, so after it passes through the brake anchor plate it can be connected directly to the air-pressure tubes fixed to the side of the compression leg. A flexible air-pressure hose joins the tubes and fitting on the anchor plate so as to allow for shock-absorber action of the compression leg.

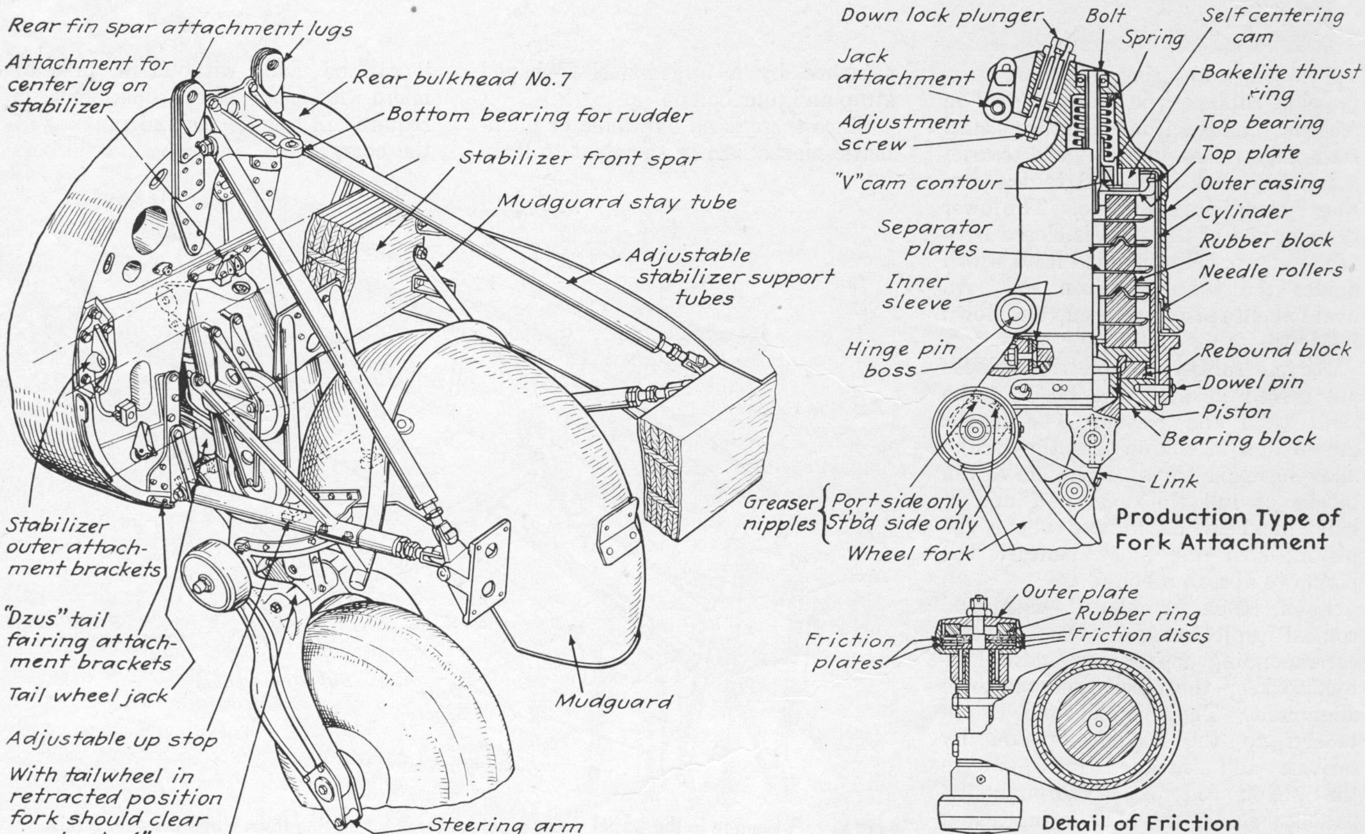


Fig. 3. A dual-tread tire, friction dampeners, and a centering cam make high-speed landings possible with this tail wheel. A rubber shock absorber takes stresses from the framework. The fin spar is supported by laminated steel lugs at the top of the bulkhead.

Since the magnesium wheel does not of itself make a good braking surface, cadmium-plated steel inserts, 0.18 in. thick, are provided. They have a 1-in. lip on the inside that is secured to the magnesium wheel with sixteen 0.312-in. bolts.

Spring-closed L-shaped oil seals are provided at each end of the axle to prevent any grease from working out of the hub and being thrown on the brakes.

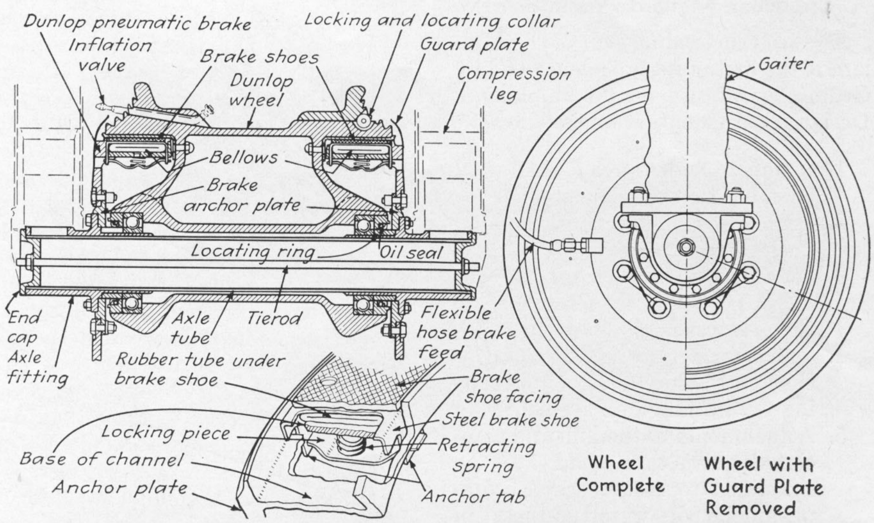


Fig. 4. A section through the landing wheel showing the arrangement of the twin pneumatic brakes mounted on a hollow axle. Brake anchor plates on each side of the wheel enclose the braking surfaces and transmit brake torque to the axle and struts. The detail shows the method of holding the brakes in position.

Gloster Meteor

The installation of the nose-wheel gear in the Gloster Meteor jet aircraft features twin heavy blocks attached to the landing gear mount to maintain proper c.g. following the removal of armament (1). The mechanism retracts backward and up into the nose fuselage well almost directly beneath the cockpit.

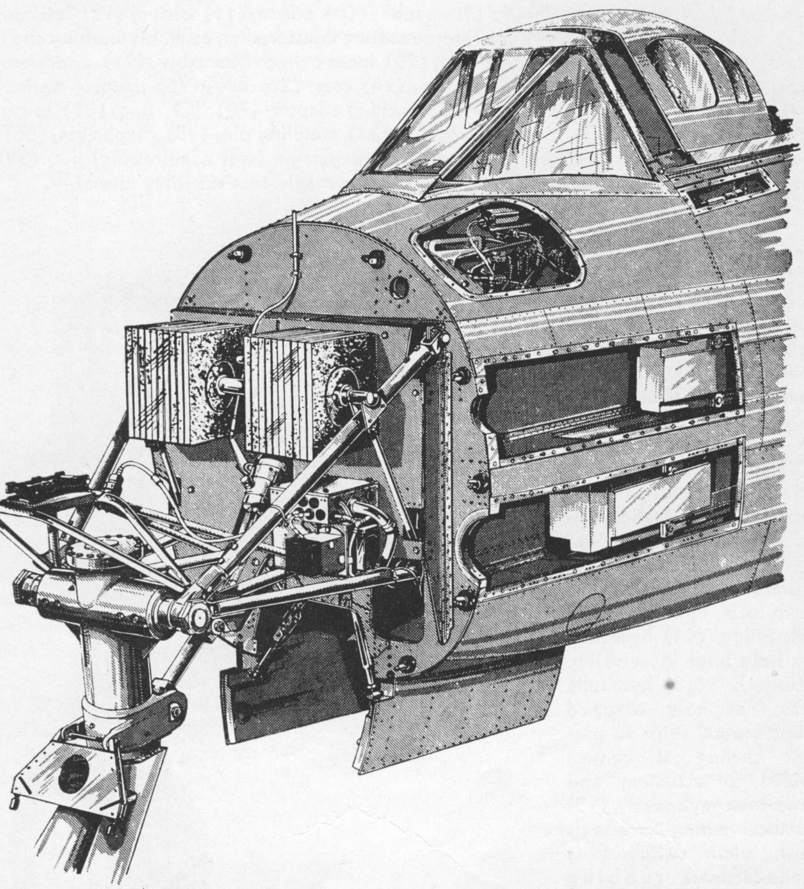


Fig. 1. The installation of the nose landing wheel in a model specially modified for high-speed flight. The heavy blocks attached to the landing gear mount are to maintain proper c.g. following the removal of armament. Note the changes in cockpit canopy, in which small transparent sections are substituted for larger bubble-type canopy, which tended to warp because of the heat generated at greater than 600-mph speeds.

Grumman Mallard Amphibian

The tricycle landing gear of the Mallard is the first of its type developed by Grumman for use on an amphibian. Design requirements were as follows:

1. A much wider tread than had been used on previous models
2. High-speed requirements dictated flush-retractable gear
3. Sacrifices in cabin volume for wheel pockets were minimized to the greatest possible extent
4. Quick retraction was essential to shorten the high drag period during the initial climb segment
5. Attachments to the hull and associated structure had to be simplified to assure easy accomplishment of watertightness in production and to maintain it during years of service
6. All moving parts had to be corrosion-resistant
7. Linkage and operating forces had to be sufficient to raise and lower the gear easily while it was being dragged through water at moderate speeds
8. Elaborate fairings and doors could not be tolerated because of rough water damage.

These specifications had to be worked out for a wheel location about 8 ft away from the wing. Several attempts to fold the wheels into the wing were discarded. Folding into the wing root required too elaborate cutouts. An earlier system of using double drag links with a parallelogram motion created an elaborate hull chamber.

The final design (1) employs only a single drag link, accomplished by making the axle integral with the shock strut. It is noteworthy that the basic three-strut tripod was the answer. The hull cutout for the wheel and cutouts for housing the articulated shock strut in the hull and wing are relatively small.

The landing gear is operated by dual hydraulic cylinders interconnected and operated by the main landing gear valve only. When the mechanical advantage of one is poor, that of the other is good, and vice versa. The cylinder on the shock strut not only provides the major portion of the lift during the early stages of retraction, but positively locks the strut in its last motion. A dashpot cushions the final motion. A no-chatter spring added to the brake disks and other simple modifications by

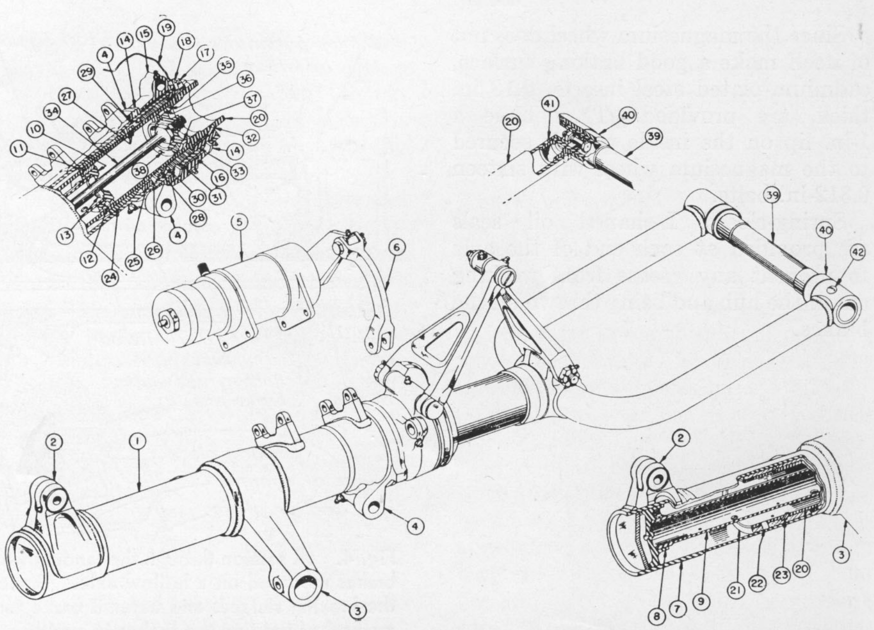


Fig. 2. The Mallard nose-wheel shock-strut details: (1) shock strut, fork and axle assembly; (2) actuating cylinder attachment; (3) trunnion (installed to fuselage); (4) wheel well door actuator ring attachment; (5) Houde shimmy damper assembly; (6) wing shaft; (7) outer cylinder barrel; (8) diaphragm; (9) piston tube; (10) orifice; (11) piston; (12) retaining pin; (13) lock screw; (14), (15), (16), (17) torque fitting thrust washer, assembly bushing and retaining nut; (18) lock screw; (19) lock wire; (20) inner cylinder assembly; (21) upper centering cam; (22) lock screw; (23) snubber valve; (24) cam; (25) key; (26) packing washer; (27) leather back-up ring; (28) "O" ring; (29) packing adapter; (30) "O" ring; (31) lower bearing; (32) wiper ring; (33) lower bearing nut; (34) metering pin; (35) diaphragm; (36) "O" ring gasket; (37) seal compressing ring; (38) diaphragm (seal compressing) nut; (39) axle assembly; (40) axle collar; (41) axle cap; (42) port-side axle retaining assembly.

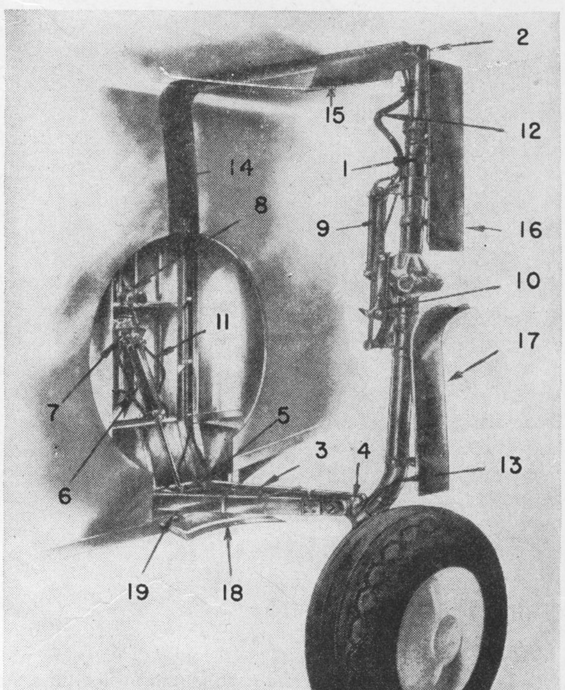


Fig. 1. The main-wheel assembly of the Mallard includes: (1) main shock strut assembly; (2) strut attachment to fitting at wing station 77; (3) drag link assembly; (4) strut attachment to link; (5) attachments for inboard ends; (6) hydraulic actuating cylinder; (7) attachment of upper end of actuating cylinder to locking mechanism; (8) bumper dashpot; (9) hydraulic actuating and down-lock cylinder; (10) lock fitting; (11) hydraulic flex hose lines to actuating cylinder; (12) hydraulic lines (flex hose wrapped with Koroseal strips to prevent chafing at contact points) to actuating and down-lock cylinders; (13) electrical wiring to wheels down micro switch; (14) pheno-laminate rubbing strip; (15) door; (16) wing fairing; (17) hull fairing; (18) door; (19) door linkage—turnbuckle assembly—barrel.

Goodyear completely eliminated an early and objectionable wheel chatter in which the whole gear was in resonance with a chattering brake.

The main wheels are located almost exactly at the main step location. This arrangement permits a small clearance between the hull and the ground, limited not to irregularities which might be encountered in a fore-and-aft direction, but to those which might appear spanwise between the wheels. The limiting clearance for this type of plane is the tendency of the rear step to hit a ramp as the fore part of the hull is water-borne. This could occur on extremely steep ramps, but it represents no problem if the pilot slowly eases his ship into the water.

The nose wheel (2) is conventional. The actuating cylinder serves as a drag strut as well as incorporating internally the up-and-down locks. The two doors are attached to the shock strut and are structurally designed to withstand 4,300 lb per sq ft. A glass window in the top of the wheel pocket affords the copilot a view of the extended wheel. Water trapped by the doors is well drained during the take-off run before the plane is air-borne.

Early service tests indicated the need for a pedestal to prevent the tail from dropping when several passengers occupied the rear portion of the cabin while the ship was on the ground. An "antisquat" strut (3) was added and is operated from the inside by a lever at the back of the cabin. The strut folds back itself if a landing is made while it is extended.

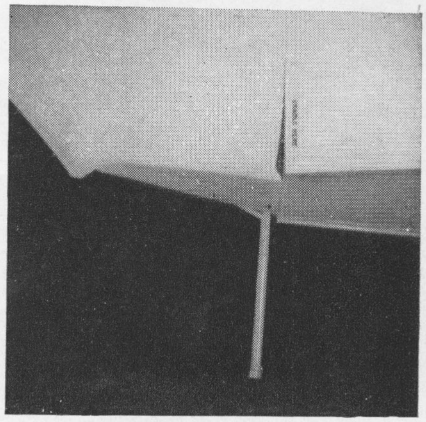


Fig. 3. The "antisquat" strut is controlled by a lever inside the cabin and prevents dropping of the aft section of the hull when the load is shifted to the rear of the cabin while the ship is on the ground.

Douglas A-20

One of the first United States military planes to be equipped with tricycle landing gear, the A-20 has a gear that is completely retractable and hydraulically operated. The main-wheel tread width is 203½ in.; wheel base, 165 in. The wheels are equipped with disk-type hydraulic brakes. The main wheel and tire size is 44 in.; nose wheel and tire, 26 in.

Each main wheel is mounted on a single braced, oleo-pneumatic strut, and the nose wheel is mounted on a single cantilever oleo-pneumatic strut. For normal operation, the nose wheel (1) is limited to a movement of 30 deg each side of center by a hydraulic snubber, but a mechanism is provided to allow full 360-deg caster for ground handling.

The main wheels (2) retract up and aft into the nacelles, while the nose wheel retracts up and aft into the fuselage. All are completely enclosed when retracted, and retraction and extension of all three are simultaneous and actuated by the same control system.

Brakes are pressure operated and individually controlled by pedals integral with the rudder pedals in the cockpit. A parking brake, operated from the cockpit, also is provided. Positive hydraulically operated mechanical locks hold the gear in the extended position. Positive extension of the landing gear in case of failure of the hydraulic system is accomplished by a bungee system and an emergency pull handle to disengage the gear lock-up mechanism (3).

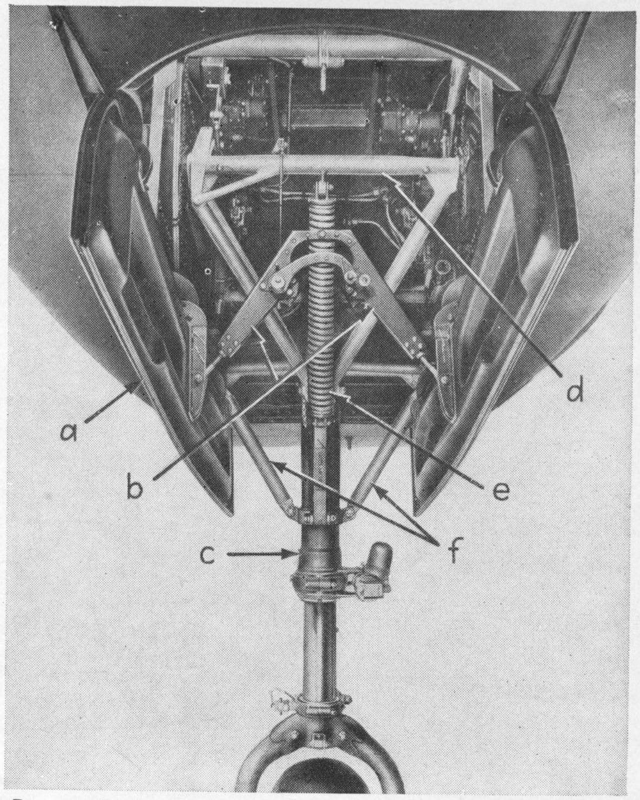


Fig. 1. Front landing wheel: (*a*) nose-wheel door; (*b*) adjustable yoke; (*c*) shock strut; (*d*) cross beam; (*e*) spring bungee; (*f*) side brace strut.

A position indicator, red and green warning lights, and a warning horn indicate landing gear position at all times.

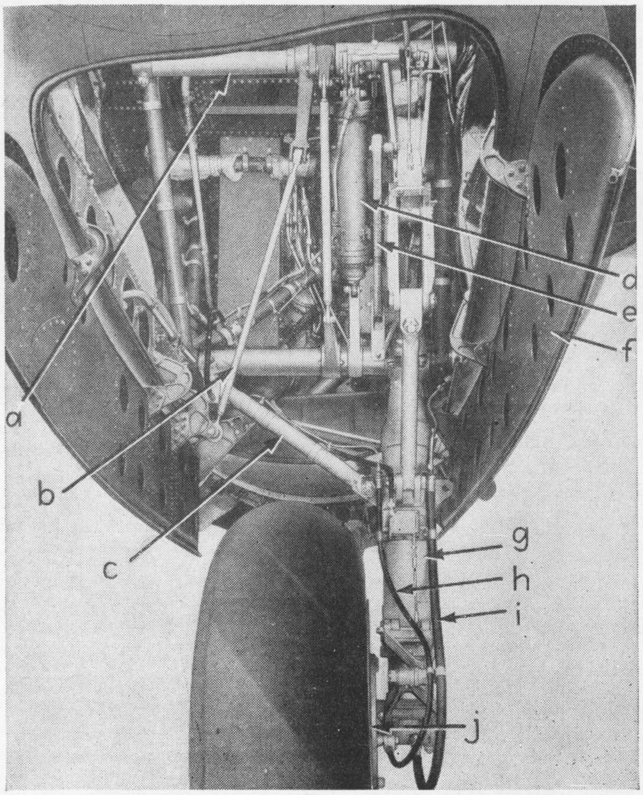


Fig. 2. Rear landing wheel: (*a*) support shaft; (*b*) door control rod; (*c*) brace; (*d*) actuating cylinder; (*e*) bungee ring; (*f*) nacelle door; (*g*) shock strut; (*h*) hydraulic brake hose; (*i*) emergency air brake; (*j*) wheel and brake.

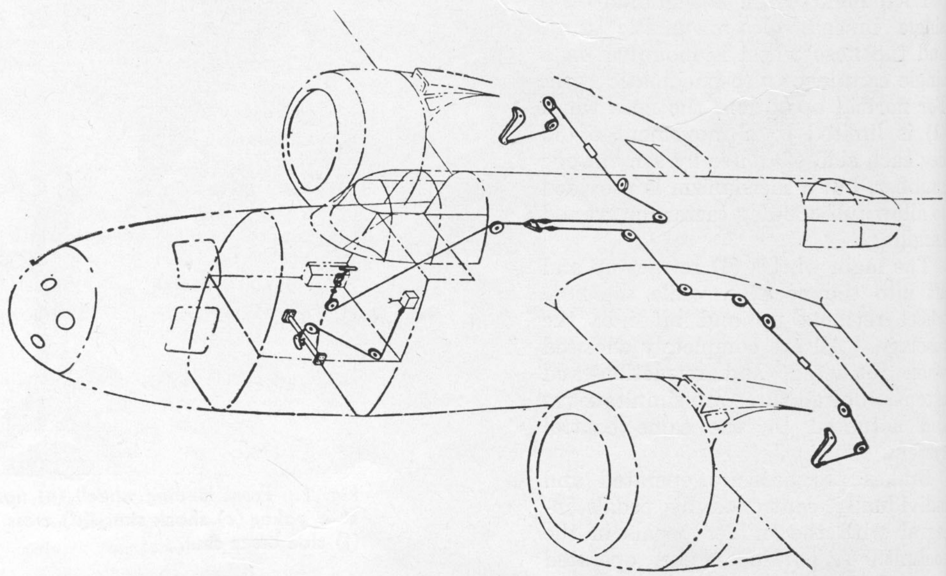


Fig. 3. The landing gear mechanical release permits wheels to drop into the extended position. A bungee provides positive impulse to start the gear moving.

Lockheed P-38

The tricycle landing gear of the P-38 is fully retractable with automatic opening and closing wheel well doors. The main gear (1) has single oleo-pneumatic shock struts with a 10-in. travel, and is hydraulically operated. The wheels are 36 in. in diameter and equipped with brakes. The main wheels retract back and up into the forward booms.

The nose gear (2) also is of single oleo-pneumatic shock-strut type with a half-type wheel fork. It is hydraulic and has a shock-strut travel of 12 in. The nose-wheel diameter is 27 in. Retraction is back and up into a well in the fuselage (3).

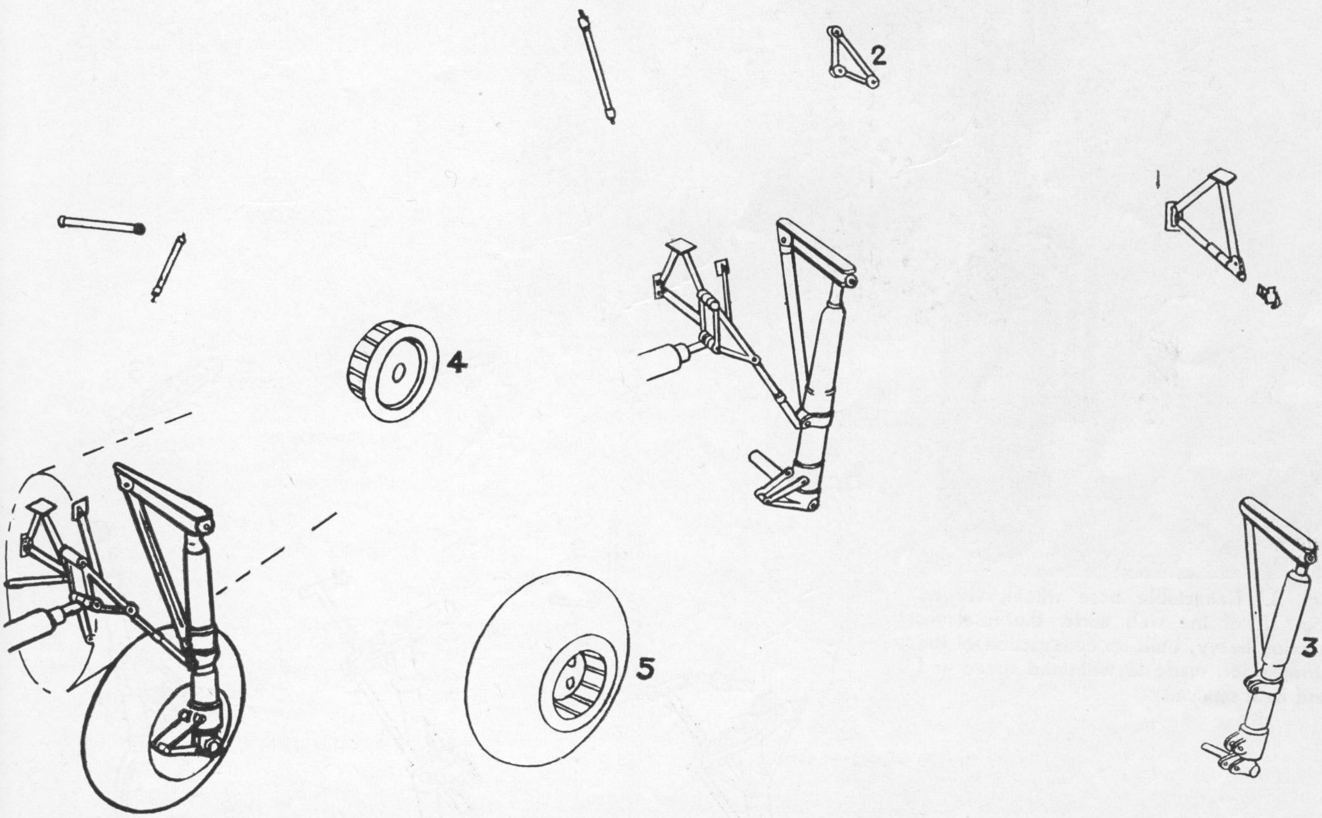


Fig. 1. The hydraulically operated main landing gear retracts up and back into wells in the forward booms. Details shown here include: (1) boom support pivot; (2) drag link; (3) main gear assembly; (4) brake; (5) wheel.

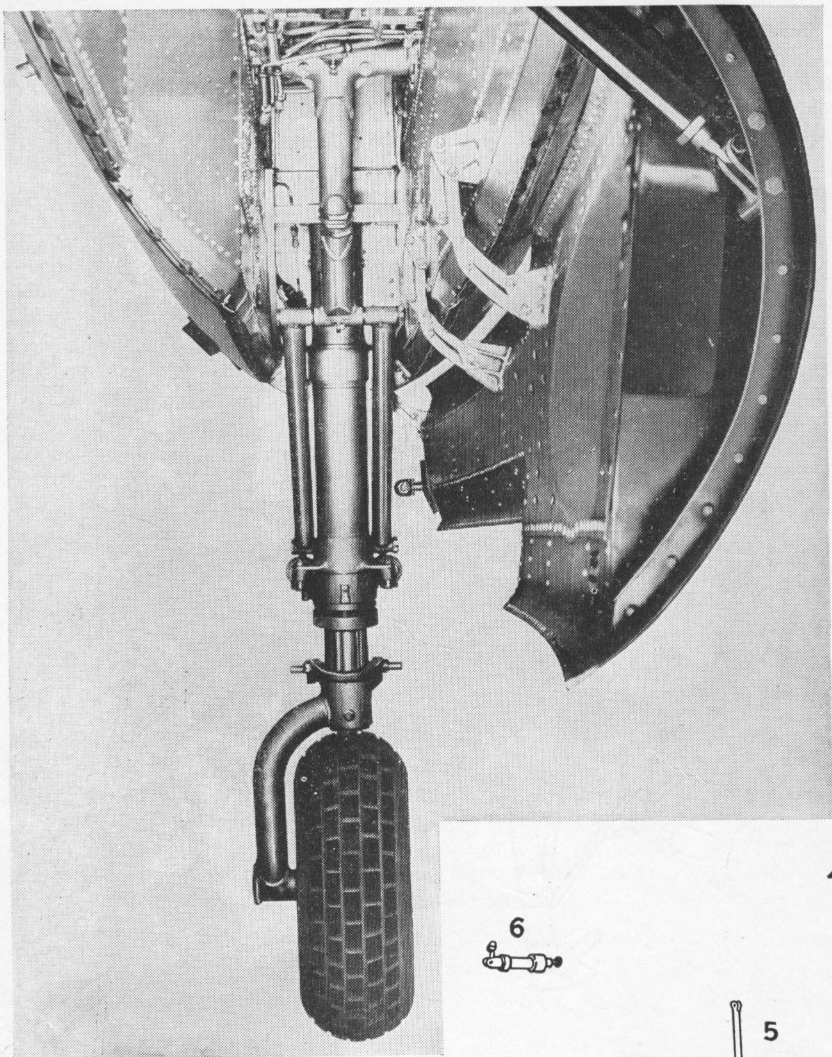


Fig. 2. Retractable nose wheel, viewed from aft of the well under the fuselage, showing heavy, built-up construction of the fairing door, made to withstand speed and hard field service.

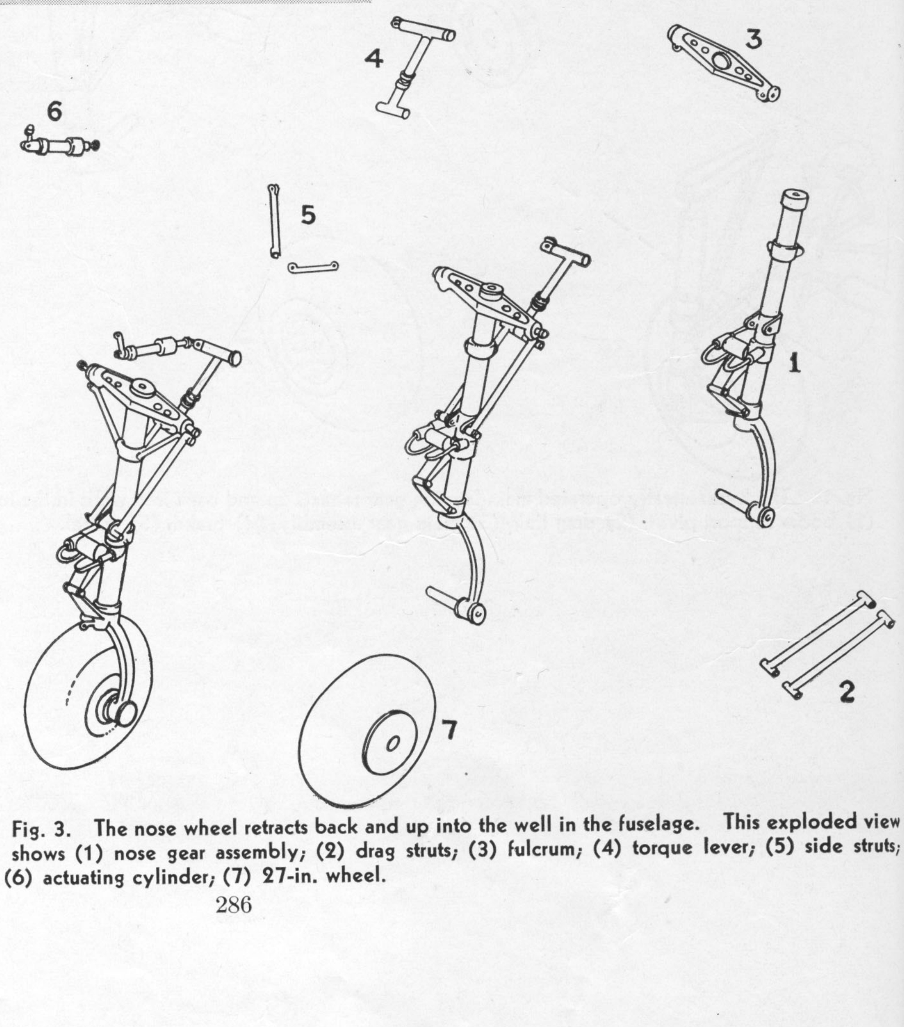


Fig. 3. The nose wheel retracts back and up into the well in the fuselage. This exploded view shows (1) nose gear assembly; (2) drag struts; (3) fulcrum; (4) torque lever; (5) side struts; (6) actuating cylinder; (7) 27-in. wheel.

PART 3. AIRCRAFT HAVING FOUR OR MORE ENGINES

Northrop B-35

Each main gear (type Ev-1 Bendix) of the B-35 consists of a pneudraulic shock strut, upper truss assembly, and an electrically operated actuator (1). Wheels are of dual type, incorporating 65-in. smooth-contour tires, and Goodyear dual-disk three-spot hydraulic brakes.

The complete landing gear assembly is supported by two large pins on the outboard and inboard sides of the gear. Each pin is retained in a clevis containing a bearing to permit rotation of the truss assembly. The strut is attached to the upper truss assembly by two large pins, also mounted in bearings, allowing movement between strut and upper truss assembly during operation.

Rear loads are absorbed by a drag brace which is attached to the bottom of the strut and hinged with bearings to the aft wheel well structure. The two main gears are interchangeable.

The main shock strut uses both air and fluid to produce controlled resistance. The strut employs two telescoping chambers, a metering pin, piston tube, snubber valve on the inner cylinder, and a fixed packing gland. Operation of the strut is conventional.

The nose gear (2), a single wheel, electrically operated steerable type, consists of a pneudraulic shock strut, free swiveling, and a hydraulically operated steer damp. The strut is attached and braced to the upper trunnion shaft, which is part of the crew nacelle.

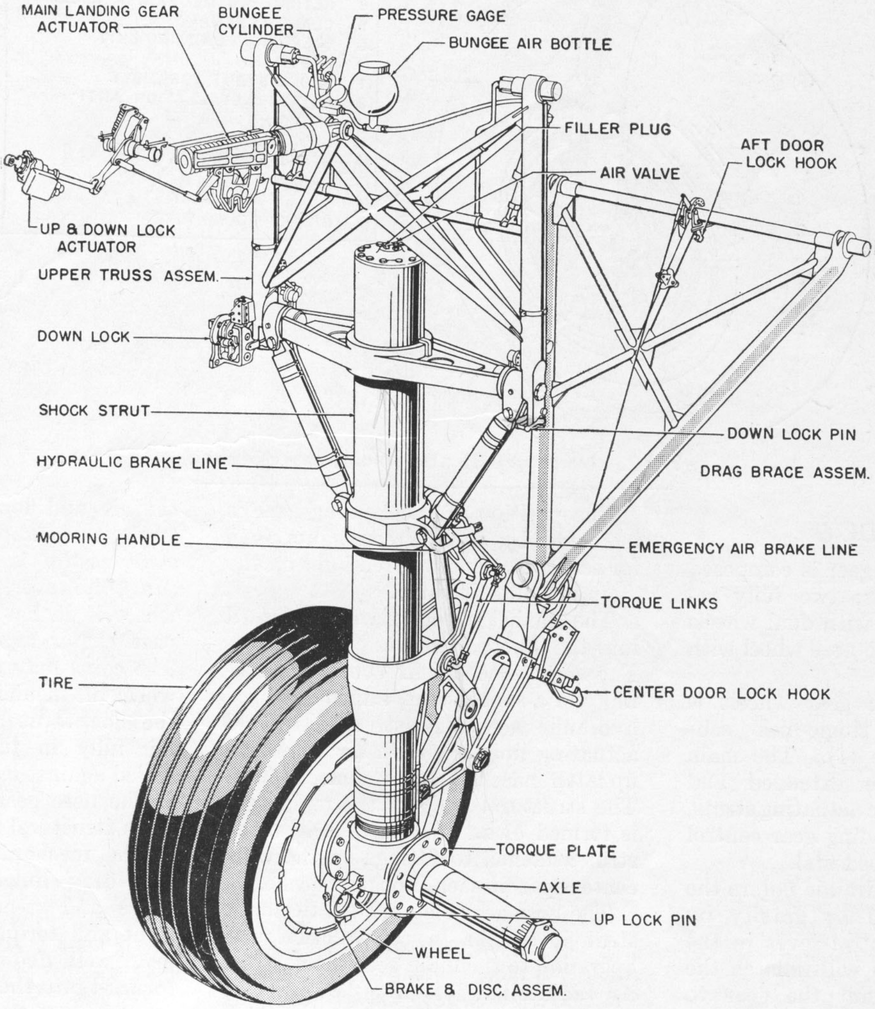


Fig. 1. Main landing gear assembly of the Northrop B-35 bomber.

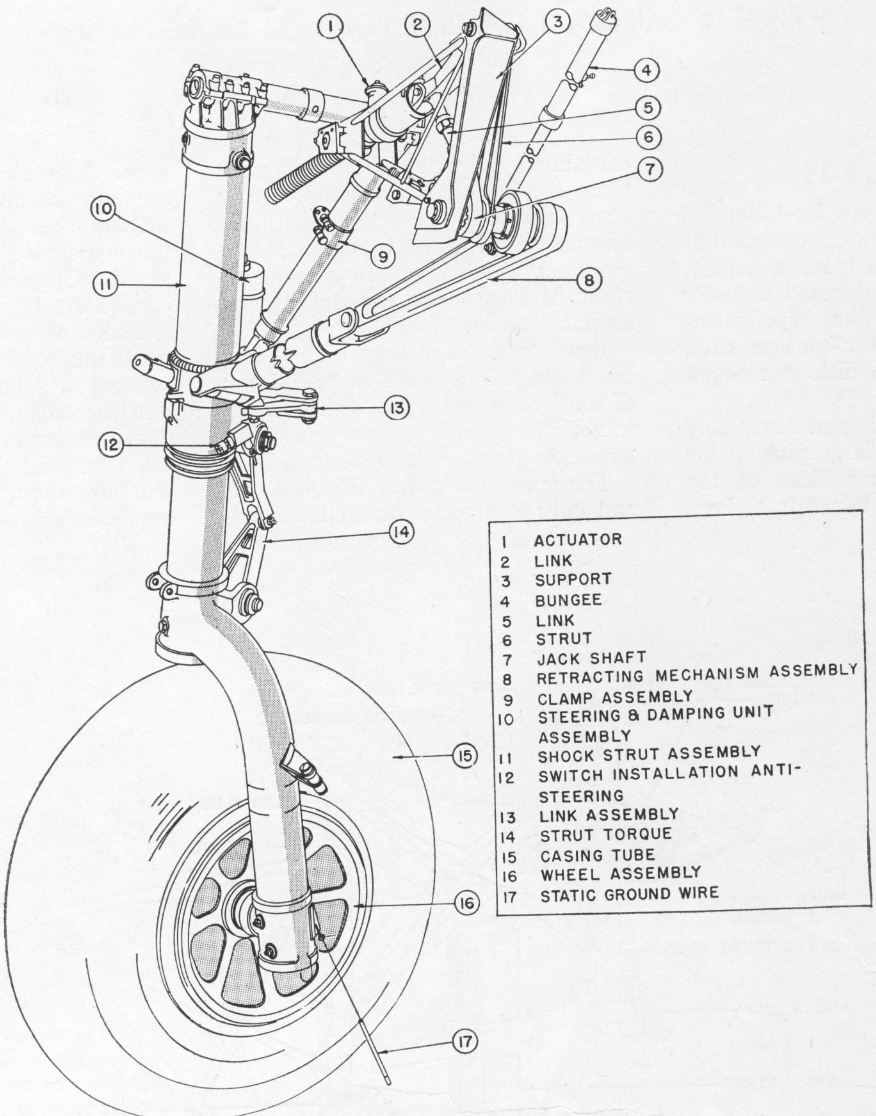


Fig. 2. Northrop B-35 nose landing gear assembly.

Douglas DC-6

The DC-6 landing gear is composed of three major units: two fully retractable main gears with dual wheels and a fully retractable nose wheel with steerable wheel.

Each of the main gear wheels is equipped with a single-disk self-adjusting spot brake (1). The main and nose gears are extended and retracted by hydraulic actuating struts, controlled by the landing gear control lever on the control pedestal.

In the event of hydraulic failure the gear can be lowered by gravity by placing the gear control lever in the DOWN position which will unlatch the up latches and permit the gear to extend by its own weight.

The position of the landing gear is indicated by three green lights (one for each gear) and one red light on the main instrument panel.

The main wheels retract forward into the inboard nacelles of each wing. The gear mechanism consists essentially of a shock strut, bungee springs, hydraulic actuating strut, drag and actuating linkage, down latch and an up latch, nacelle doors and mechanism. The structural body of the main gear is formed of an oleo-pneumatic shock strut attached to fittings on the wing center spar at each inboard nacelle.

The nose gear oleo-pneumatic shock strut is similar in construction and operation to the main gear shock strut. An additional feature, however, is included—a centering cam device which centers and locks the wheel in the straight, forward position when the strut piston is extended. Centering cams, however, will not center the wheel if it has been turned 30 deg past center at the time of take-off. The cams may also fail to center the wheel if insufficient air pressure in the shock strut prevents it from extending fully in take-off. The strut is sealed against leakage by 0 rings.

The nose gear oleo strut forms the main structural member. Other parts of the mechanism include retracting and drag linkage, nose wheel side brace and steering collar, a bungee strut and torque links, and the nose gear well doors. The gear retracts forward into the well (2).

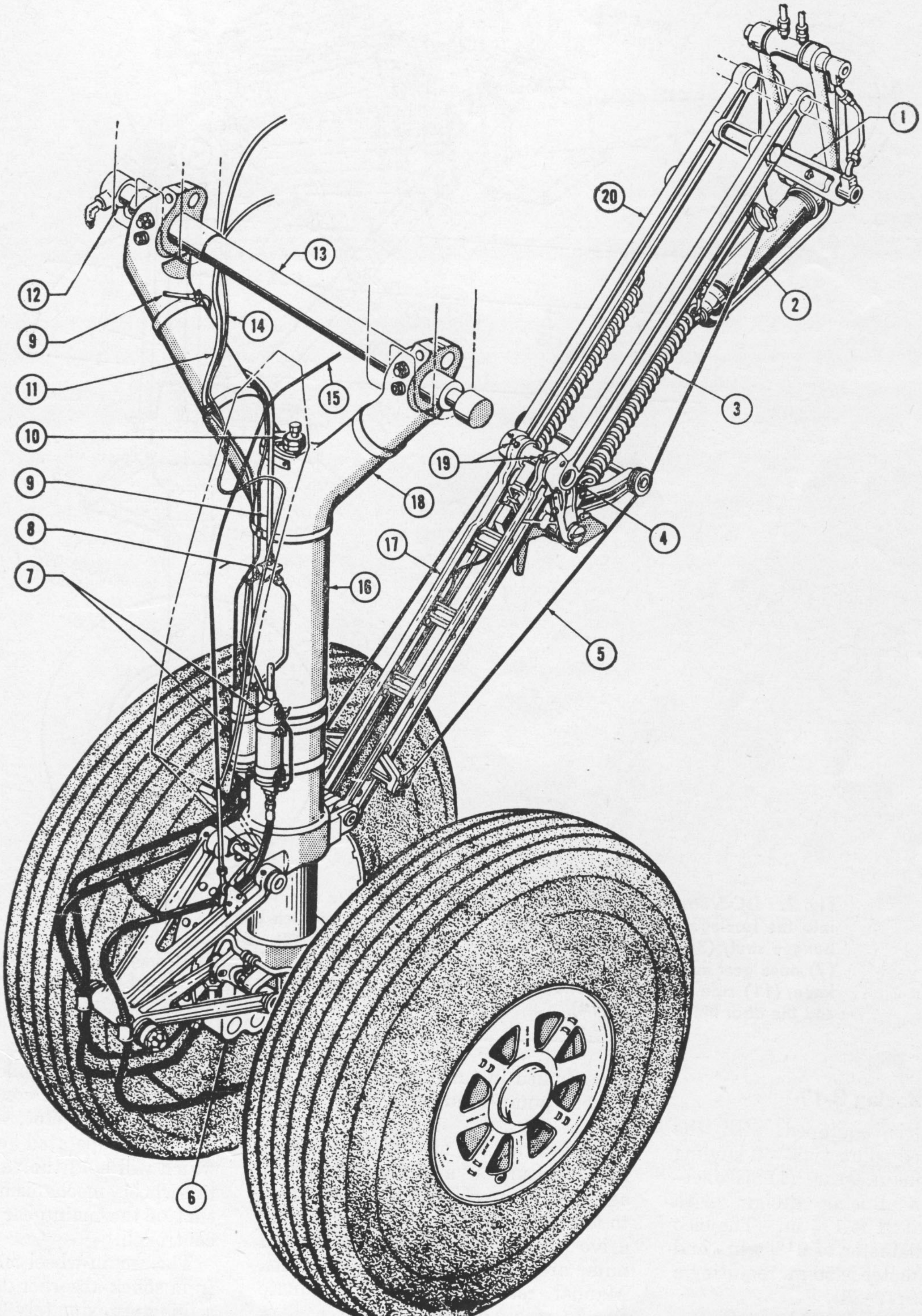


Fig. 1. The main landing gear of the Douglas DC-6 includes: (1) actuating strut linkage; (2) hydraulic actuating strut; (3) bungee spring; (4) drag linkage knee; (5) bungee cables; (6) self-adjusting spot brake assembly; (7) brake lockout cylinders; (8) Wye fitting; (9) hydraulic brake line; (10) shock-strut oil-air valve; (11) air brake line; (12) hydraulic brake gland; (13) axis tube; (14) conduit from safety switch (right main gear only); (15) antiretraction Arens control cable (right gear only); (16) shock strut; (17) lower drag linkage; (18) shock-strut fork; (19) Zerk fittings (typical); (20) upper drag linkage.

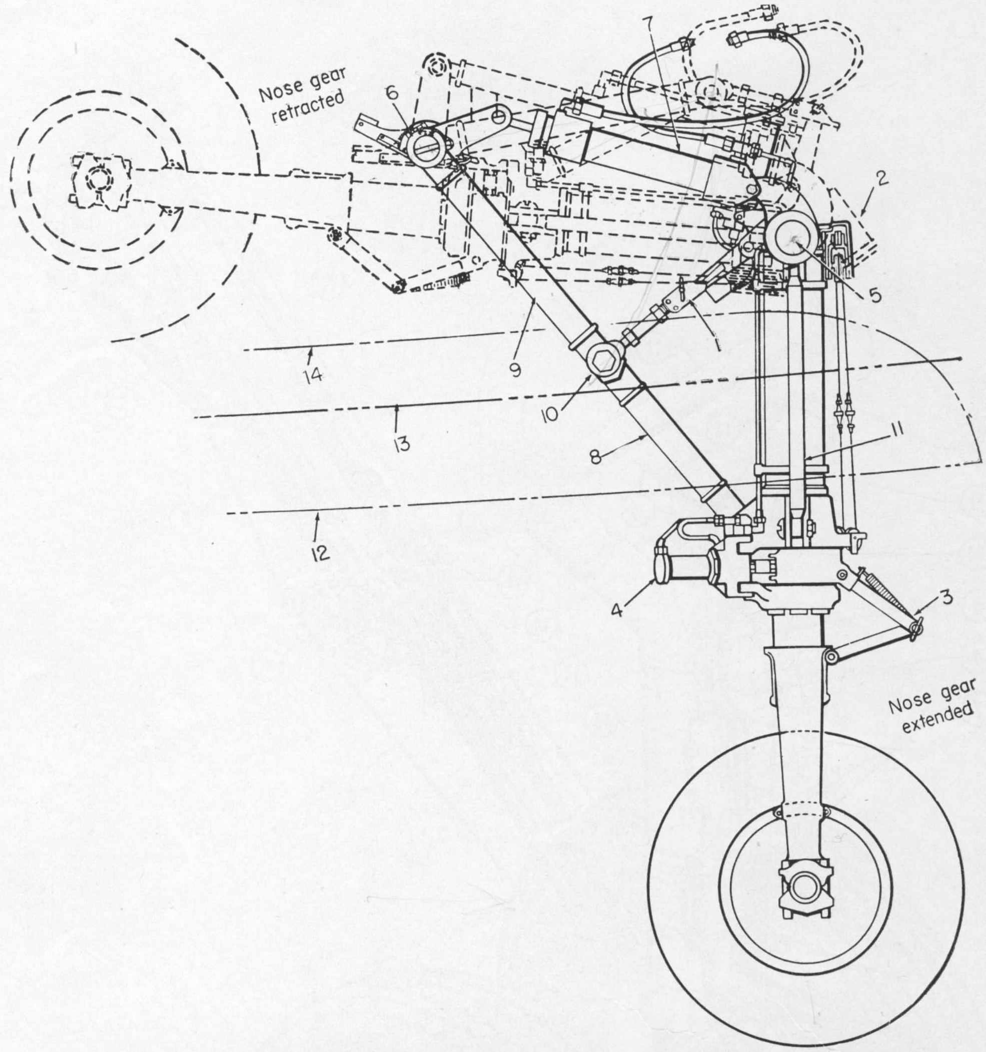


Fig. 2. DC-6 nose gear positions: In a retracted position the wheel is moved forward and up into the fuselage well. The mechanism includes: (1) down-latch linkage; (2) down-latch bungee strut; (3) torque links; (4) steering struts; (5) main pivot; (6) drag linkage pivot; (7) nose gear actuating strut; (8) lower drag link; (9) upper drag links; (10) drag linkage knee; (11) side brace link. The nose well door line is shown open at (12), closed at (13), and the door hinge line at (14).

Boeing B-17

The B-17 is equipped with the standard three-point type of landing gear. The main gear (1) is oleo-pneumatic, a Boeing design, with tread width of 21 ft 1½ in. The oleo strut has a diameter of $9\frac{19}{32}$ in., and the wheel diameter is 56 in. requiring a 16-ply tire (56:19–23).

Retraction of the main gear is upward and forward, leaving a small portion of the wheel exposed when fully retracted (2). The tail wheel retracts fully.

The brakes are dual hydraulic, obtaining pressure from an accumulator supplied in turn by an electrically driven pump and emergency hand pump.

The retracting mechanism of each leg consists of a retracting screw actuated by an electric motor attached to the screw by gearing, and a manual drive shaft. Retracting screws and nuts are interchangeable as units. Manual retracting shafts terminate on the rear side of the front wall of the bomb bay and are operative by the engine starter crank. The right and left legs retract simultaneously when motor-driven; individually when cranked.

The brakes are operative through the pilot's and copilot's pedals, but the parking brake control is operative only by the copilot. It consists of a manually operated eccentric device which will hold the valves open. The tail-wheel mechanism is similar to that of the main gear and is similarly controlled.

The main-wheel motion resulting from shock-absorber deflection is along a line approximately 20 deg aft in the level landing position. Friction in the gearing and screw mechanism is sufficient for locking and for absorbing kinetic energy of the moving mechanism after power is cut off.

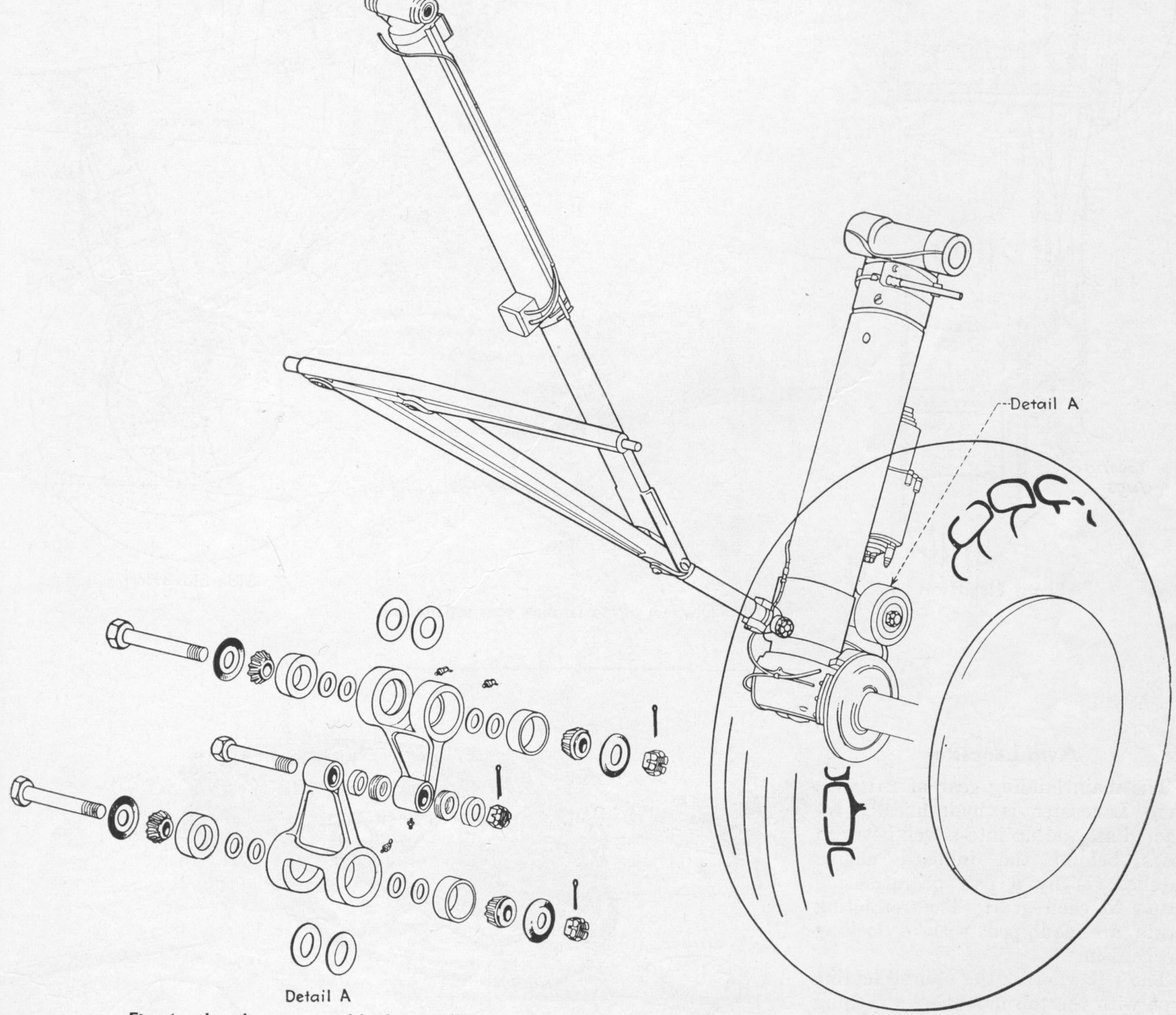


Fig. 1. Landing gear and brake installation. Detail *A* shows an exploded aspect of the torsion link assembly.

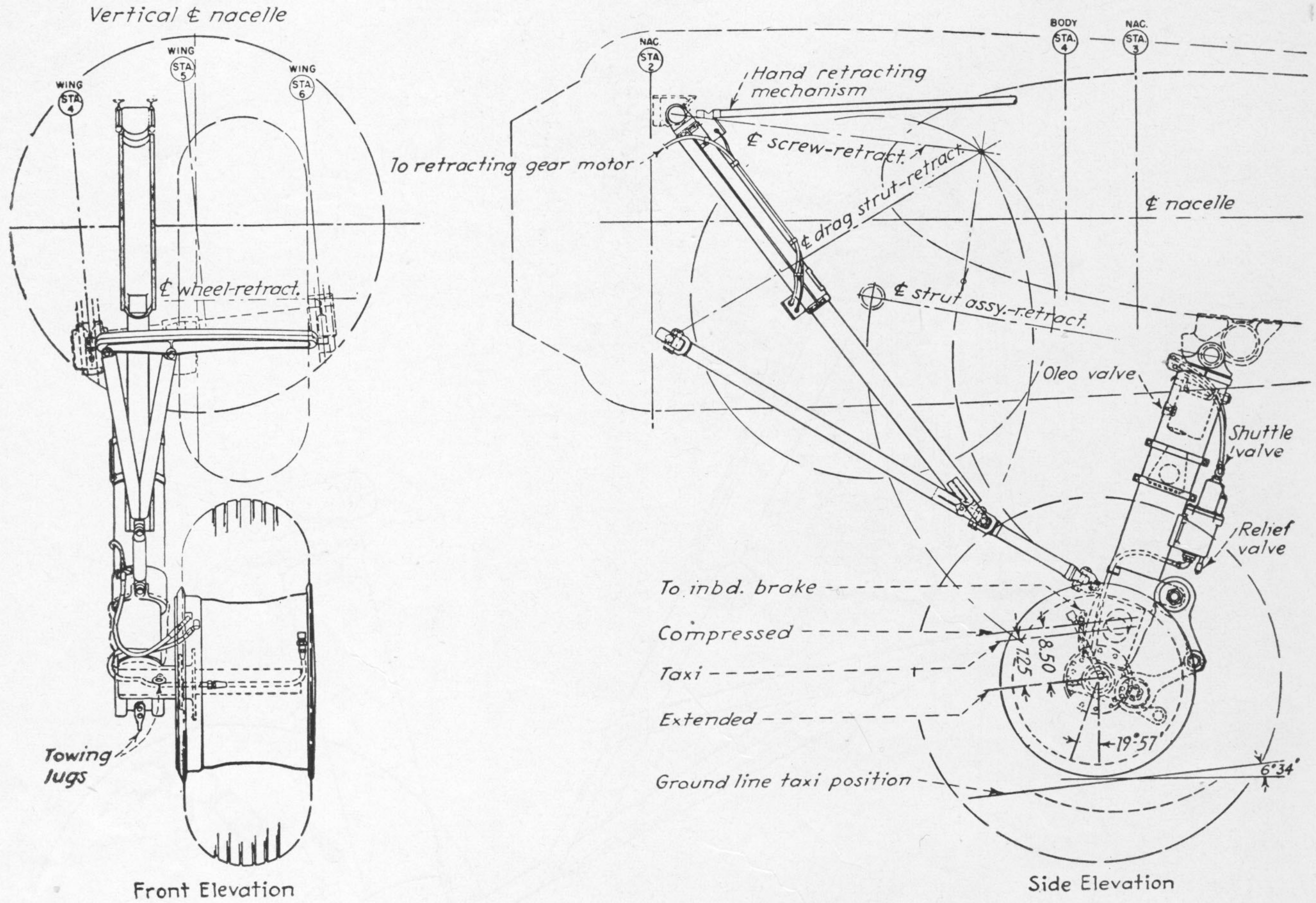


Fig. 2. Diagram of the landing gear installation.

Avro Lancaster

The main landing gear of Britain's Avro Lancaster is hydraulically retracted aft and up into a well between spars behind the inboard engine nacelles (1) by a pair of retracting struts to each gear. The retracting struts are equipped with a locking mechanism.

The tail wheel is the nonretractable type with the top mounting attaching to the stabilizer front spar web (2).

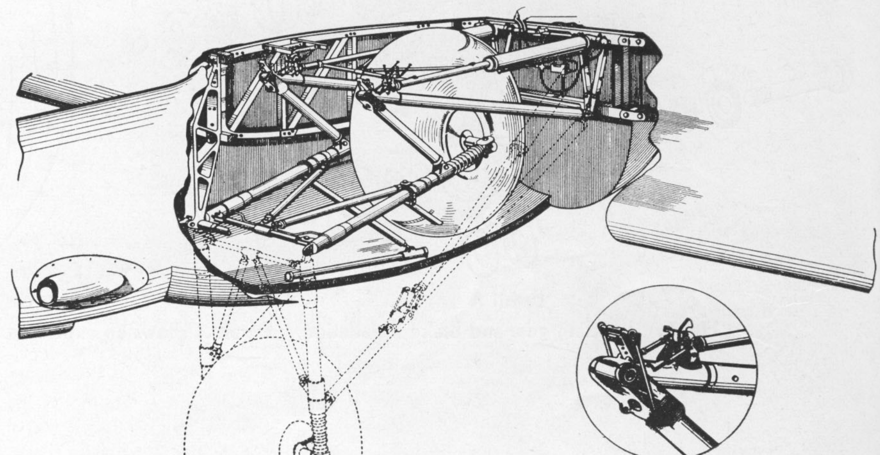


Fig. 1. Phantom view showing the method of retracting the Lancaster main landing gear, in which the wheel is hydraulically pulled aft and up into a well between spars behind the inboard engine nacelle. The detailed sketch in the circle at the lower right gives an enlarged view of the retracting strut locking mechanism.

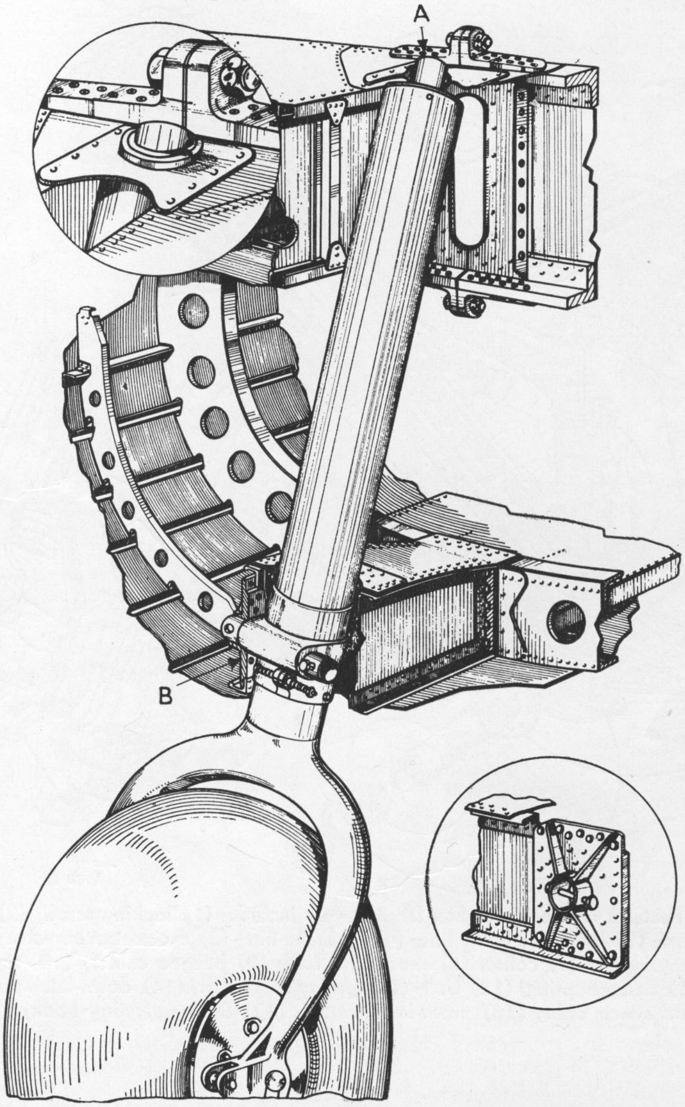


Fig. 2. Details of mounting the nonretractable tail wheel on the Avro Lancaster, with the top mounting (*A*), which attaches to the stabilizer front spar web, enlarged in the circle at the top; the bottom mounting point (*B*) enlarged in the circle at the lower right.

Canadair North Star

The North Star's landing gear is composed of three units: two fully retractable main gears with dual wheels and brakes, and a fully retractable nose gear with a steerable wheel. Extension and retraction of the main and nose gears are accomplished by hydraulic actuating struts which are controlled by the landing gear control lever on the control pedestal. In event of failure of the hydraulic system, the gear may be lowered by operation of the landing gear emergency extension control.

A faired nonretracting tail skid supported by a shock strut protects the fuselage tail section from possible damage in a tail-down landing.

The main dual-wheeled landing gear (1) retracts forward into the inboard nacelles of each wing. Each main landing gear includes a bungee spring, hydraulic actuating strut, drag and actuating linkage, down and up latches, safety and warning light switches, and nacelle doors and mechanism.

The bungee is a spring held under heavy tension to pull the down latch into locked position if the landing gear should extend under its own weight. The actuating strut is a conventional two-way type operating under pressure of 3,000 psi. Fore-and-aft loads on the landing gear are taken by drag linkage extending between the collar on the lower portion of the shock strut and an attachment fitting on the front spar. The drag linkage is composed of an upper and a lower drag link which join to form a down latch at the knee. The down latch locks the gear securely in the DOWN position. The piston rod of the actuating strut is attached by the eyebolt to a lever on the down latch. During retraction, the first action of the strut is to rotate the down

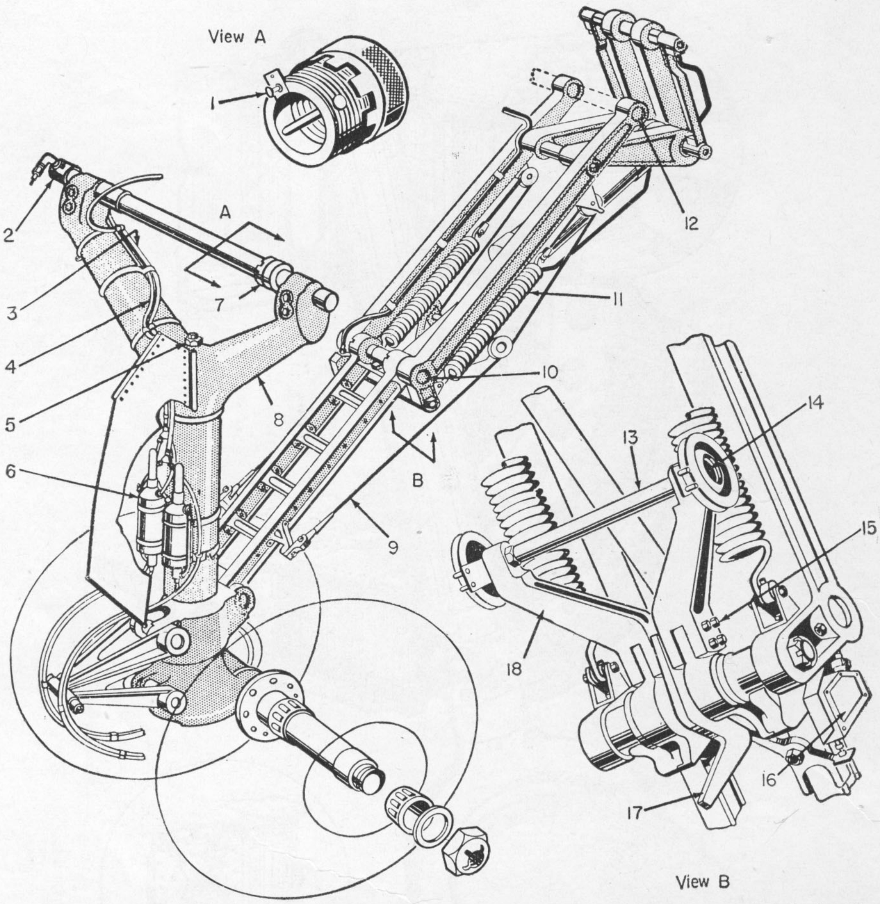


Fig. 1. Features of the North Star landing gear include: (1) locking screw; (2) hydraulic brake gland; (3) hydraulic brake line; (4) air brake line; (5) shock-strut air valve; (6) brake lock-out cylinders; (7) collar; (8) shock-strut fork; (9) bungee cables; (10) drag linkage knee; (11) bungee spring; (12) bolt; (13) pulley spacer bar; (14) down-latch pulleys; (15) pulley arm attach bolts; (16) down-latch switch; (17) door operating hook; (18) pulley arms.

latch until it unlocks, permitting the knee joints to break.

A Cleveland Pneumatic Tool oleo-pneumatic shock strut is attached to fittings on the center spar in each inboard nacelle. Both air and fluid are used in the struts to produce controlled resistance to shock during take-off and landing. The static weight is carried by the air in the strut upper chamber, and this air serves to extend the strut to place it in position to take the next shock load. The impact energy of landing and energy developed in taxiing are absorbed by both the air and the fluid.

A hydraulically operated disk-type brake is installed on each main landing gear wheel (2). Brake system pressure is 3,000 psi. A small accumulator, installed in the nose gear well, opposite the steering accumulator, on the right side of the bulkhead, maintains a reserve of fluid pressure for parking the brakes.

The brake control valve, operated by a system of levers connected to the rudder pedals, limits the fluid pressure from 390 to 500 psi, which is required for brake operation. The pressure applied to the rudder pedals will control the amount of fluid pressure delivered to the brakes. When toe pressure is applied, the rudder pedal will swivel about the pivot in the rudder pedal assembly and not affect the action of the rudder when the plane is on the ground.

Two brake lockout cylinders, mounted on each shock strut, transmit hydraulic pressure to the main gear wheels. The lock-out cylinders prevent hydraulic failure in one of the brakes from affecting operation of the other.

The nose gear is suspended from the nose gear well. It retracts forward into the well and is enclosed by contoured doors. The steerable wheel is supported by a yoke attached to the lower end of the shock strut piston, and is braced by folding drag linkage (3).

Hydraulic power applied to the actuating struts extends and retracts the gear and steers the wheel. The gear is locked in DOWN position by a knee linkage or down latch attached to the drag linkage. In the UP position the gear is locked by a mechanically operated up latch.

When the nose gear is retracted, hydraulic pressure first operates the

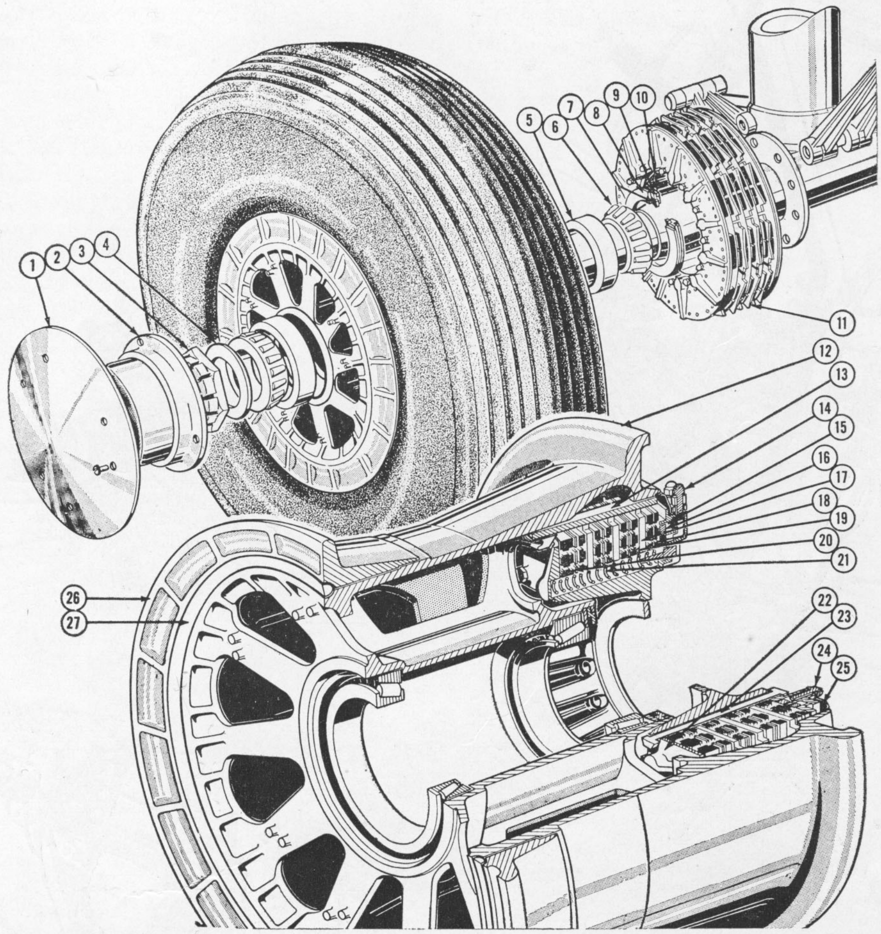


Fig. 2. The main gear wheel and brake installation of the North Star include: (1) fairing assembly; (2) hub cap; (3) retainer nut; (4) washer; (5) bearing cap; (6) bearing cups and rollers; (7) felt washer; (8) washer; (9) retainer cup; (10) snap ring; (11) brake assembly; (12) wheel and bearing cup assembly; (13) rotor drive key; (14) bleeder screw assembly; (15) piston cups; (16) piston; (17) rotor segment; (18) lining; (19) stator plate; (20) pressure plate assembly; (21) piston return spring; (22) backing plate assembly; (23) drive sleeve and bolt; (24) adjusting screw; (25) carrier assembly; (26) wheel flange; (27) flange retainer.

spring-loaded bungee to break the down-latch knee, then extends the actuating strut which pushes the gear upward. As the gear swings up into the well, the shock-strut piston engages a saddle assembly which pulls the doors closed.

The oleo-pneumatic shock strut is similar in construction and operation to the main gear shock strut. However, one additional feature is included in the nose gear strut—a centering cam device which centers and locks the wheel in the straight, forward position when the strut piston is extended. Thus the gear cannot be retracted with the wheel turned to either side.

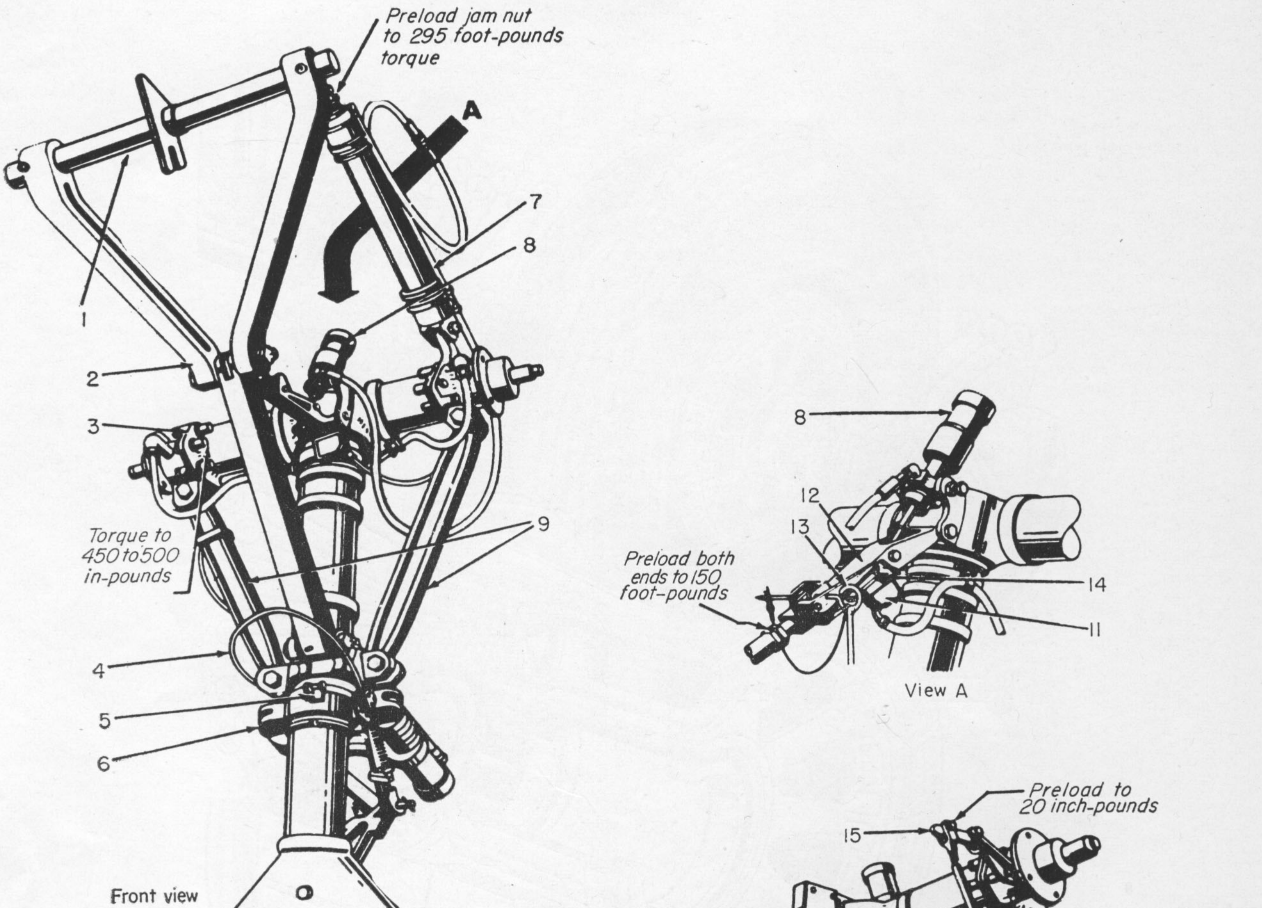


Fig. 3. The nose gear of the North Star includes: (1) upper retracting link axis tube; (2) drag linkage; (3) yoke gland; (4) Arens control assembly; (5) up-latch spacer; (6) steering collar; (7) actuating strut; (8) bungee strut; (9) side brace link; (10) down latch; (11) down switch; (12) switch arm; (13) ground safety lock; (14) plunger screw; (15) steering control valve actuating cam; (16) shock strut; (17) steering strut; (18) upper and lower torque links.

Consolidated Vultee B-24

A tricycle-type landing gear of the B-24 has a fore-and-aft wheel base of 16 ft and a main gear width of 26 ft 7½ in. In addition to the main gear (1) and nose wheel (3), a retractable tail skid (2) is provided which, while not strong enough for full tail landing loads, will withstand the load of rocking after landing. It is supported by an alclad sheet box structure built into the lower aft end of the fuselage, below the aft gun position, and is extended and retracted hydraulically.

The main gear wheels are Air Corps type 111, made of aluminum alloy or magnesium alloy castings, requiring 56-in. by 16-ply tires. The nose wheel is fitted with a 36-in. by 10-ply tire.

On the main and nose gears, hydropneumatic struts are used, with main gear retracting outward and upward into wells in the undersurface of the center wings. The nose wheel retracts upward and slightly aft into a well just forward of the cockpit floor. The nose wheel is held in the UP position by a latch, and the door closing the opening is actuated by the gear mechanism.

The main gear assembly is supported from two false or auxiliary spars located just outboard of the inboard engine cowling, between the front and rear spars. They are plate girder type of heavy rolled angles and flat sheet riveted to two of the main wing bulkheads. Both gears are equipped with emergency release and retraction mechanisms. The brakes are duplex expander tube type.

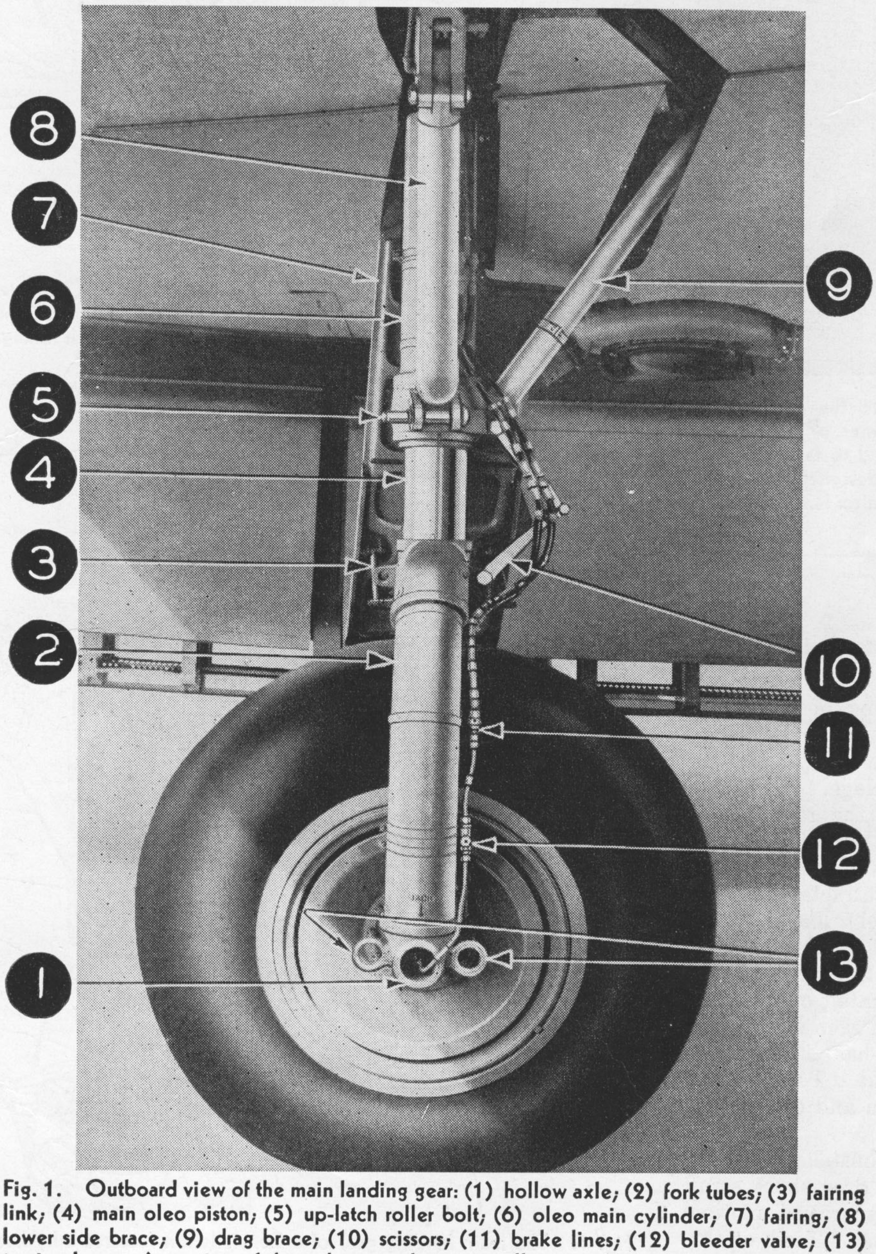


Fig. 1. Outboard view of the main landing gear: (1) hollow axle; (2) fork tubes; (3) fairing link; (4) main oleo piston; (5) up-latch roller bolt; (6) oleo main cylinder; (7) fairing; (8) lower side brace; (9) drag brace; (10) scissors; (11) brake lines; (12) bleeder valve; (13) towing lugs. A portion of the turbosupercharger installation is seen to the right of the drag brace.

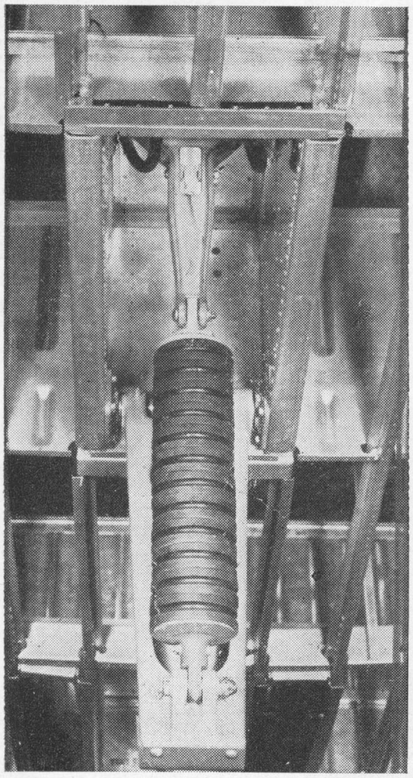


Fig. 2. Seen here are the retractable tail skid and the manner of mounting. The skid is not intended to take full tail landing loads but is designed to withstand the rocking load after landing.

Lockheed Constellation

The Constellation has a tricycle landing gear consisting of two main gears located in the inboard nacelles and wing, and a nose gear in the forward part of the fuselage. A retractable tail bumper in the rear of the fusleage protects the aircraft in event of accidental tail-down landing. The landing gear is fully retractable.

Each main gear (1) has a single oleo-pneumatic strut with an axle fastened directly to the strut piston. Dual wheels are mounted on the axle which extends out on each side of the strut. Each wheel has a multiple-disk type of brake unit. Torque arms keep the shock piston and cylinder in alignment.

A feature of the Constellation main gear is the hydraulic drag shock strut designed to permit rearward motion of the gear on landing. Tests of the drag strut have shown that initial landing load peaks were reduced by

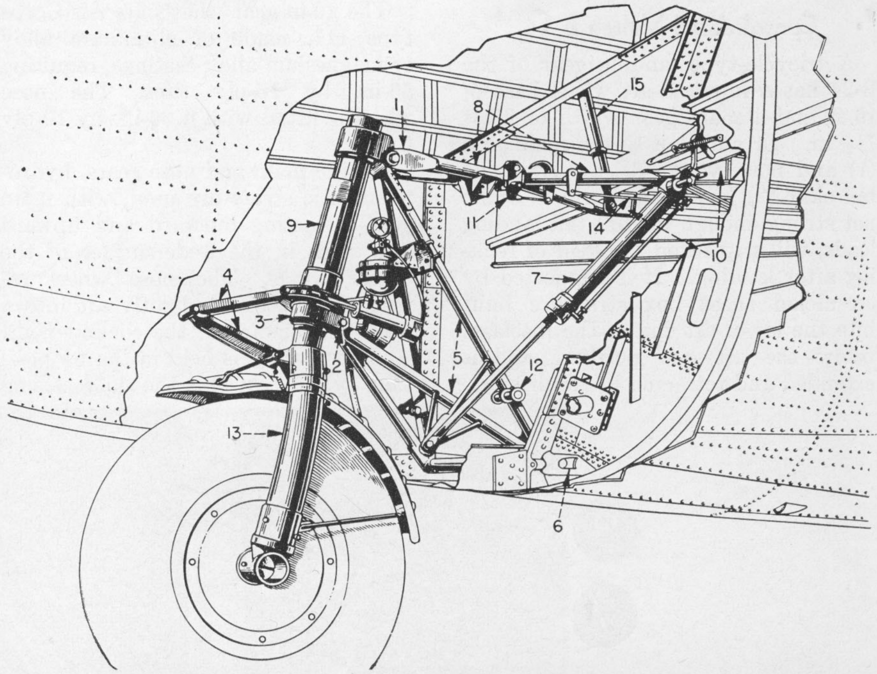


Fig. 3. Details of the nose gear: (1) and (2) strut bolt; (3) lower collar; (4) scissor; (5) V struts; (6) pivot shaft; (7) hydraulic jack; (8) drag link assembly; (9) strut; (10) hinge shafts; (11) latch; (12) roller assembly; (13) fork; (14) latch linkage; (15) booster spring.

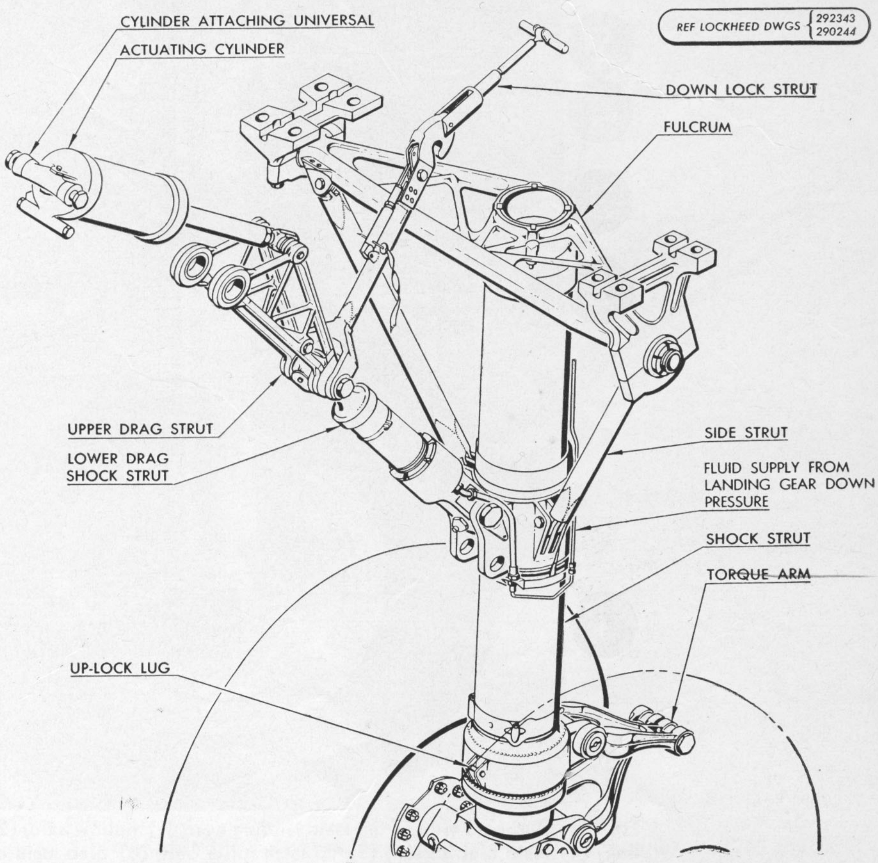


Fig. 1. The main landing gear of a Constellation features a hydraulic drag strut which permits rearward motion of the gear on landing, reducing the peak loads by as much as 32 per cent in normal landings.

as much as 32 per cent in normal landings. The drag strut assembly consists of an upper and lower strut which transfers part of the landing load to the wing structure and also retracts the gear. The hydraulic actuating cylinder rotates the drag strut, thus folding the drag strut assembly and retracting the gear forward and upward into the wheel well.

The nose gear (2) uses a single oleo-pneumatic shock strut having a dual-wheel axle attached directly to the end of the strut piston. A fulcrum fastened to the top of the shock-strut cylinder pivots on spherical bearings mounted on the fuselage structure.

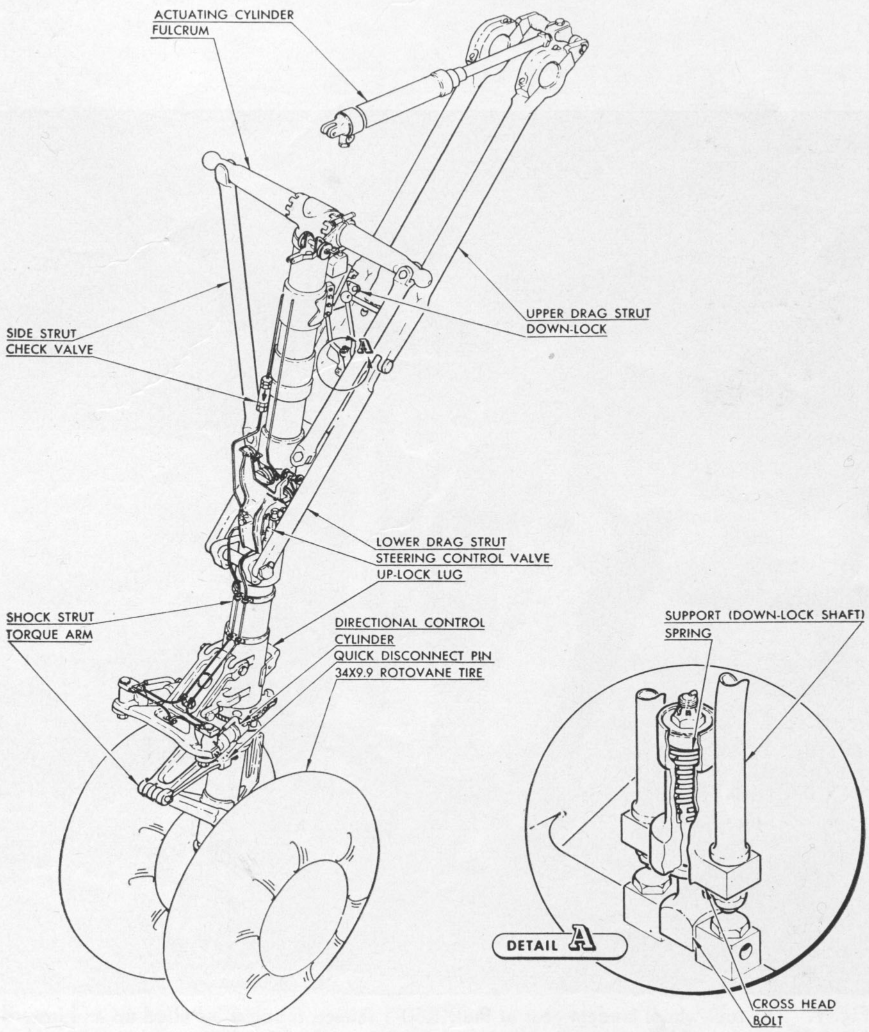


Fig. 2. The Constellation nose gear assembly.

Lockheed Constitution (XR60-1)

The Constitution is equipped with four-wheel main tandem landing gear to take the weight of the 180-passenger, 92-ton aircraft. The wheels retract inboard, pulled up and inward by double retracting struts. This action pulls shut the wheel door attached to the main hydraulic struts and the underwing hinge attachment (1).

Fig. 1. The four-wheel tandem gear of the XR60-1 retracts inboard. Pulled up and inward by the jointed double-retracting struts, the wheel door is closed at full retraction. The main gear is installed just aft of the inboard engine nacelle.

Chapter VI. CONTROL SYSTEMS

PART 1. SINGLE-ENGINE AIRCRAFT

Republic Seabee

The Seabee's instrument panel (1)* is on the left side of the cockpit in front of the pilot. A package unit in the lower right corner contains Electric-Autolite automotive-type engine instruments: oil temperature gauge, oil pressure gauge, fuel quantity and pressure gauges, tachometer and ammeter. By removing four nuts which hold four clamps in the rear of the package, the latter may be removed into the cockpit.

A two-way Hallicrafters radio is adjacent to the left engine panel package; by removing four screws on the underside of the support shelf forward of the panel, and disconnecting power supply, antenna, and phone plugs, the radio may also be drawn into the cockpit.

The microphone is spring-clipped on the instrument panel, and the cord passes through the panel, drawn in from behind by spring tension. An optional radio, with broadcast band and loop antenna provisions, fits the standard installation brackets without any alteration.

The flight panel package contains an air-speed indicator, magnetic compass, altimeter, and ball-bank indicator. The package is drawn into the cockpit by prying off the false front, then removing eight screws on the panel face. Optional flight panel is equipped with a sensitive altimeter, bank-and-turn indicator, clock with sweep secondhand, and the standard-equipment airspeed indicator and magnetic compass.

The instrument panel also carries the following control switches: Cole-Hersee master switch, and Douglas or Cole-Hersee dome light, instrument light, anchor light, and running light switches. The Pollak or Bendix ignition switch is designed to control the starter by pressing the key in BOTH position. The key for the ignition switch also operates the cabin-door locks.

Other panel controls are pulls for the parking brake, carburetor heat, carburetor mixture, and throttle. Signal lights for landing gear lights also are installed.

The right half of the cockpit panel is omitted to provide free passage to the bow door.

Production installation time for all electric wiring on the craft is approximately 11 min. Wires are furnished in prefabricated terminal lengths. Spring terminal sockets on switches are used to afford push-pull connections, and knife disconnects are used where wing and tail wires join the cockpit connections.

* The numbers in parentheses refer to the illustrations.

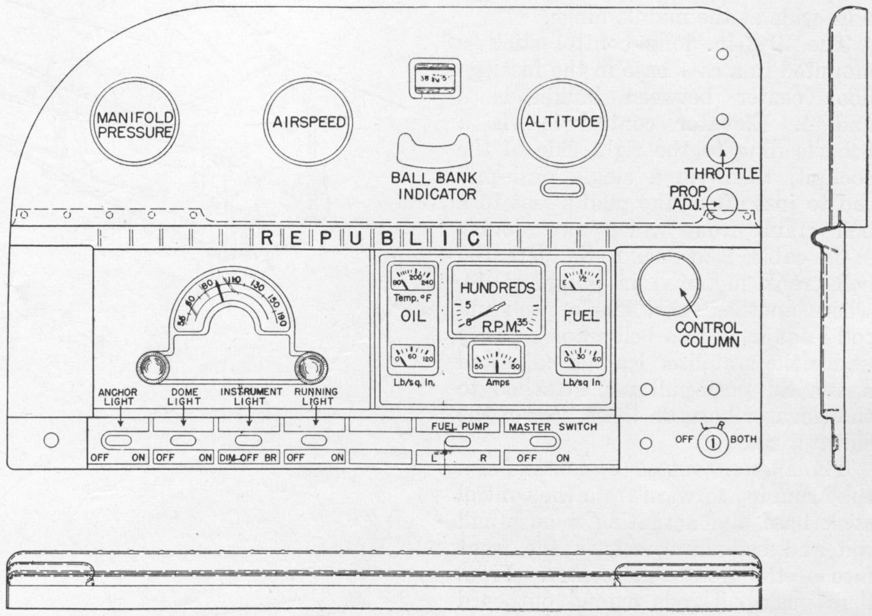


Fig. 1. General aspect of the instrument panel. A manifold pressure gauge (not standard equipment) is used in connection with a controllable pitch propeller installation (optional). In addition to the units designated on the panel, other devices installed are pulls for the parking brake, carburetor mixture, and carburetor heat, signal lights for landing gear position and a, microphone.

Focke-Wulfe FW-190

The stick and rudder controls of the FW-190 generally are the conventional push-pull rod and cable type (1) except that the elevator and rudder controls embody differential bell cranks which give a higher control surface-to-stick or rudder ratio near the neutral position, thus tending to smooth out control action at high speeds.

Stirrup-type rudder pedals with heel plates are provided, and the hydraulic brake cylinder is an integral part so that exerting toe pressure energizes the system (2). The distance of the pedals from the pilot's seat can be adjusted individually by turning a knurled knob set in the push-pull rod on each side of the cockpit aft of the pedals themselves. There are also four positions for the pedal fulcrum point.

Rudder pedal units are suspended

from brackets attached to fuselage bulkhead 2. Push-pull rods lead directly aft through the fuselage up to the differential bell crank which is suspended from the top longeron at bulkhead 13. From there cables lead aft inside the empennage skin and attach to the rudder spar, which is 4 in. wide at the middle hinge.

The 21¼-in. long control stick is mounted in a cast base in the fuselage floor center between bulkheads 3 and 4. Elevator control is via a tube leading to the right side of the cockpit, then via a single push-pull rod to just aft of the pilot's seat to a bell crank from which two double ¼-in. cables lead back to a differential bell crank mounted in bulkhead 14, where another short single push-pull rod leads back to a bell crank directly under the stabilizer leading edge and a vertical push-pull rod attached to the elevator horn on the center of the elevator spar.

The aileron control (3) consists of a tube running forward from the control stick base and actuating a push-pull rod and bell crank set on the front face of the front spar center. From here push-pull rods extend outboard through an idler hinge to change direction corresponding to the 5-deg dihedral to a point directly in front of the flap-operating motor where a bell crank changes direction aft to the front face of the rear spar. Here another bell crank changes direction along the rear spar to the inboard end of the aileron where still another bell crank and push-pull rod attach to the aileron horn.

All hinges and connections are mounted on self-aligning ball bearings so that there is little lost motion even when the bearings get loose.

The Germans' extensive use of ball bearings is particularly evident in the FW-190 controls, for finely built bearing units are found not only throughout the complicated differential bell cranks, but wherever moving parts are joined, and in all the electric reduction gears and motors (4).

The aileron stick gearing is 3.2 deg to the inch; the elevator stick gearing is 4.1 deg; and the rudder pedal gearing is 6 deg to the inch.

An electric motor-driven screw jack (5) mounted in the L.E. of the vertical fin, with the hinge point along the spar at the trailing edge, adjusts the stabilizer angle of attack (6).

The outstanding control of the plane

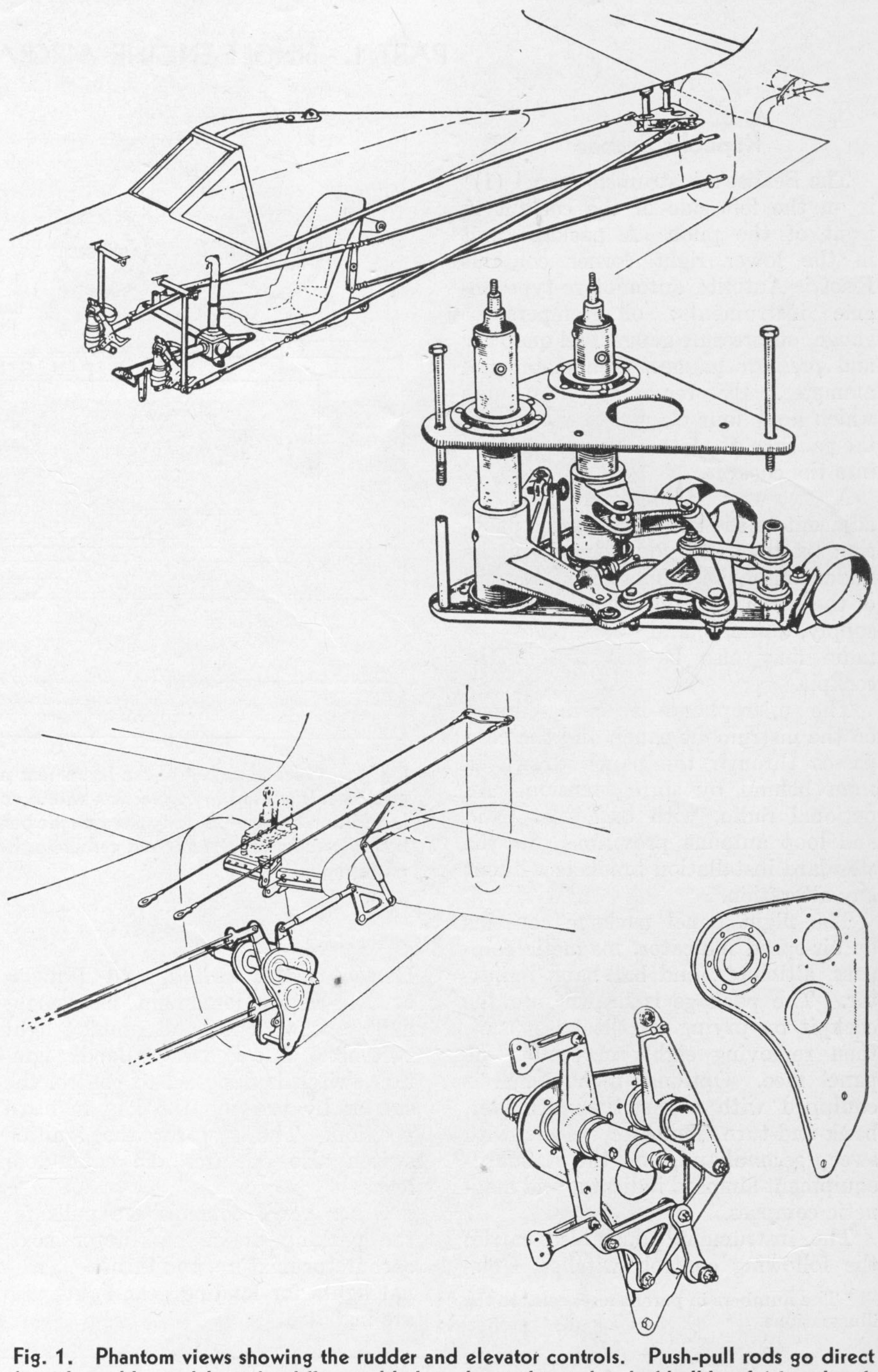


Fig. 1. Phantom views showing the rudder and elevator controls. Push-pull rods go direct from the rudder pedals to the differential linkage located just ahead of bulkhead 14 in the aft fuselage. From this linkage, cables go inside the vertical fin to the rudder connecting points. Elevator controls go from the stick via the tube to the right side of the fuselage, then via a push-pull rod to bulkhead 8 from which point two double cables lead back to the differential unit located below the stabilizer adjusting motor. The bell crank and push-pull rods lead from the differential to the elevator horn. Both rudder and elevator differential units are shown in the detail sketches.

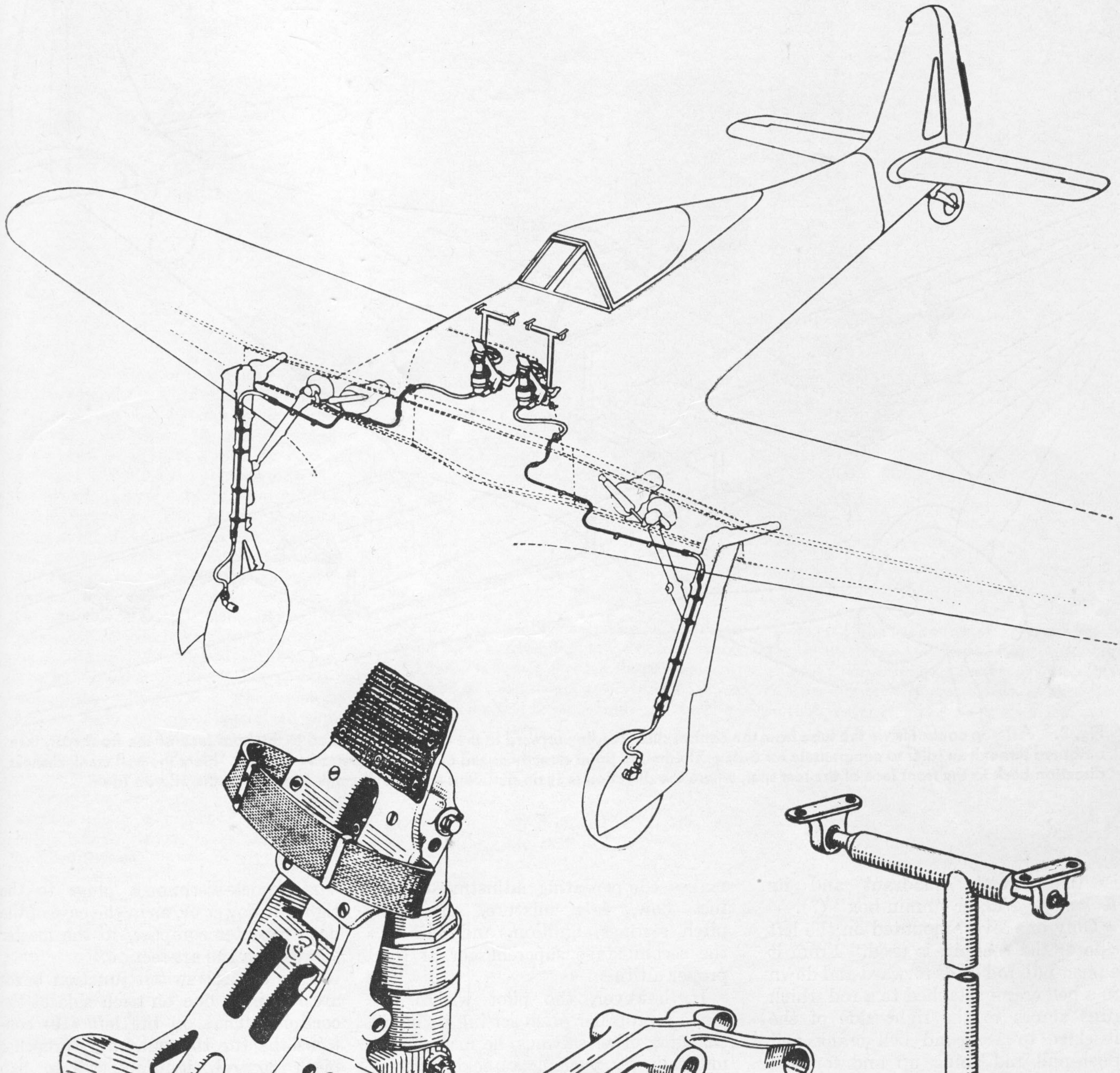


Fig. 2. The arrangement of the hydraulic brake lines is shown in this phantom view. The hydraulic piston, which forms an integral part of the rudder pedal, is clearly shown in the detail sketch at the lower left. A pedal hanger, which is ball bearing-mounted, is shown in the center, and a pedal support bracket is at the lower right.

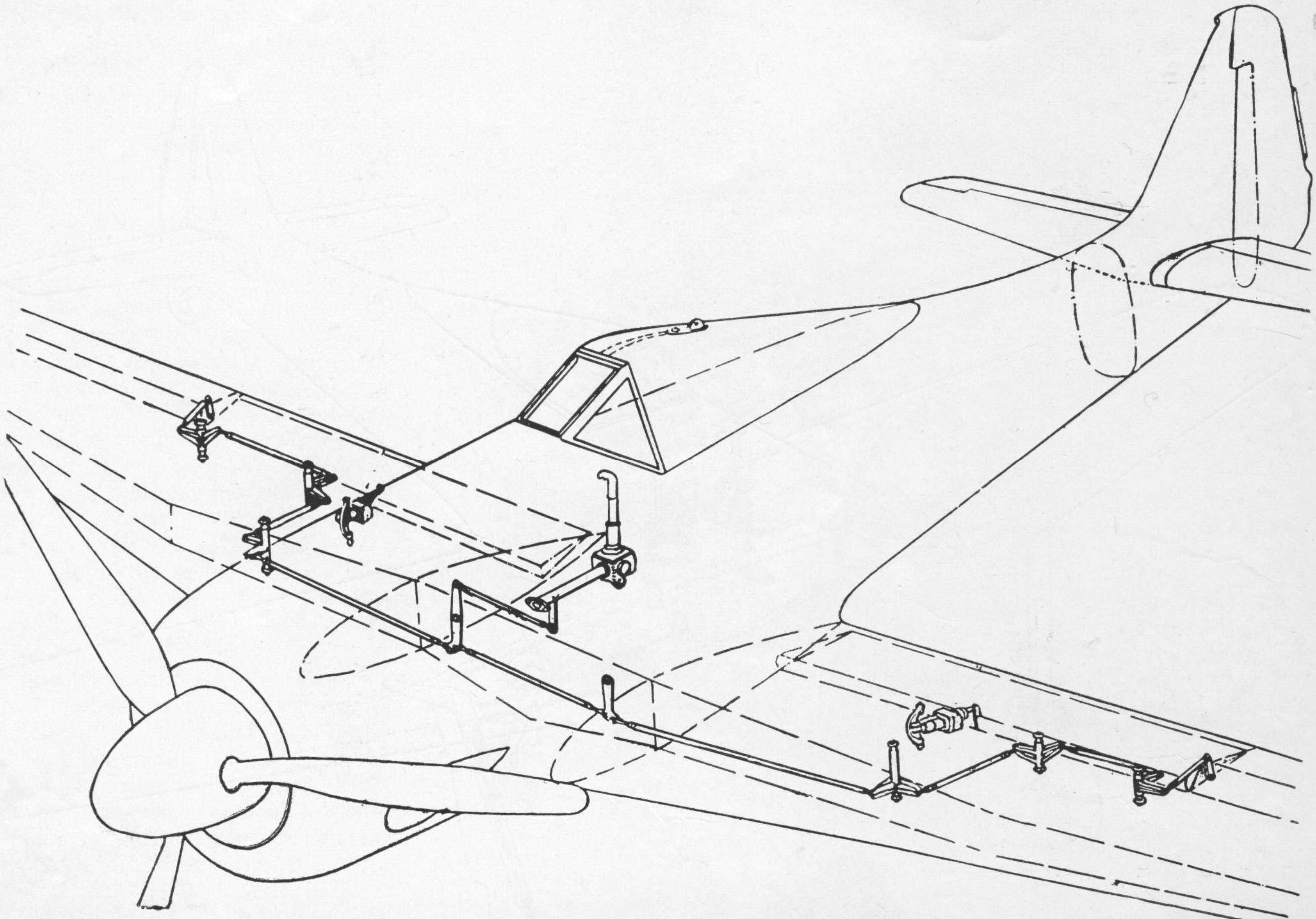


Fig. 3. Aileron control is via the tube from the control stick, leading forward to the bell crank attached to the front face of the front spar, then outboard through an idler to compensate for 5-deg dihedral, to point directly ahead of the flap-operating motors. Here the bell crank changes direction back to the front face of the rear spar, where the direction is again outboard to the bell crank attached to the aileron itself.

is the throttle quadrant and its *Kommandgerat,* or "brain box" (7).

Only one lever, mounted on the left side of the cockpit, is used. From it a push-pull rod leads forward and down to a bell crank attached to a rod which runs across to the right side of the fuselage to a second bell crank and push-pull rod going up and forward through the fire wall to another push-pull rod bell crank and the tube unit which takes the movement to the left again a few inches (to a point inside the engine mount ring) and another bell crank and push-pull rod which connects with the brain box, a finely built complicated unit measuring 16 by 16 by 12 in.

As the pilot moves the throttle and as the movement is transmitted through the bell cranks and push-pull rods, the brain box automatically makes compensating adjustments for fuel flow, fuel mixture, propeller pitch settings, ignition, and cuts in the second-stage supercharger at the proper altitude.

If, however, the pilot wishes to make a propeller pitch setting without changing other settings, he may do so manually by pushing a rocking lever switch set in the throttle.

Most of the highly complex electric system components are located to the right side of the plane's center line (8). On this side, for example, are the distributor, two generators, battery, and main junction box with its ground supply connecting plug, this latter unit being located in the aft fuselage between bulkheads 8 and 9.

Wires leading from the removable top instrument panel (9)—containing six flight instruments—go out through three quick-disconnect plugs to the right for power or, as in the case of the dash repeater compass, to the master compass in the aft section.

Two control switch junction boxes are required, one on each side of the cockpit. That on the left (10) contains the throttle quadrant, propeller pitch control, ignition switch, flap and landing gear indicating lights, starter mixture control, stabilizer trim switch and indicator, flap and landing gear switches, primer pump switch, and radio. It is built as a removable unit, and wires going out from its front end are led through three quick-disconnect plugs, those out the back end to the main junction box through five lines in two similar plugs.

The right-hand panel contains the forward and rear circuit breakers, external battery indicator, fuel booster

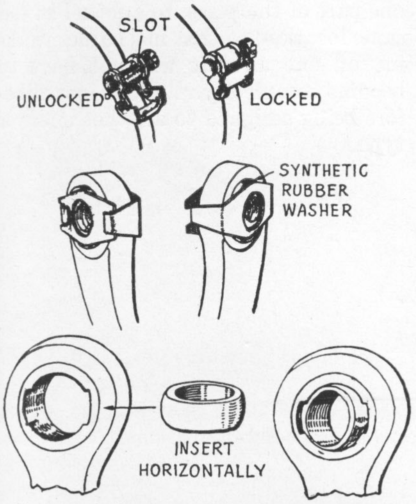


Fig. 4. Indicative of the lavish attention to design and the wide use of ball bearings are the details shown in these sketches. At the top is seen the open and closed position of a wind-up device on straps which hold hydraulic lines on the landing gear. Note the ratchet locking device. The center sketches show how ball bearings used on brackets are peened in place, then protected by felt washers and held by simple metal clamps. All elevator hinges, for example, use this type. In many places, as shown in the lower sketches, ball joints are provided. A notched ball-bearing race is pressed into place, then a ball-shaped ring is slipped in. When rotated into operating position, it cannot fall out; it provides a self-aligning connection. This type of unit is used on rear spar attachments, lower engine mount attachment to front spar, on all jacks, shock-absorber connections, and other points where stresses might be raised by fixed fittings.

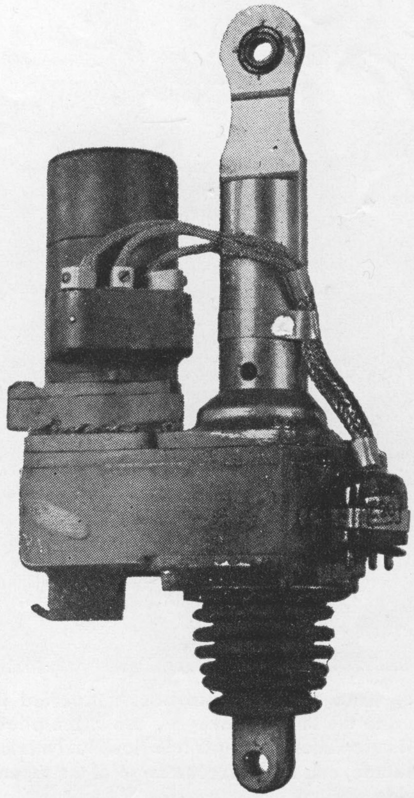


Fig. 5. The stabilizer adjusting unit, with ball and socket at the top for attaching to the inside of the fin L.E. and fitting at the bottom for attaching to the stabilizer. The electric motor runs at 14,000 rpm and, through six gear trains with 533-to-1 reduction gear, moves the stabilizer over the full adjustment arc in about 20 sec. A magnetic brake keeps it from overrunning when the current is turned off. A bellows-type rubber sleeve at the bottom of the screw jack keeps it clean.

pump switches, and engine starter. Four quick-disconnect plugs are installed in the front end; seven in the rear leading to the main junction box.

The electric system is complicated further by the fact that four of the six guns—the two 7.9-mm machine guns, and the two in-board 20-mm cannon—must be synchronized to fire through the propeller. The synchronizing units are mounted behind the engine. Electric leads go from them to each gun.

Wherever possible, wires are grouped when leading from one part of the plane to another through generous use of quick-disconnect plugs. In general, too, the FW-190 follows the German practice of having wires leading from

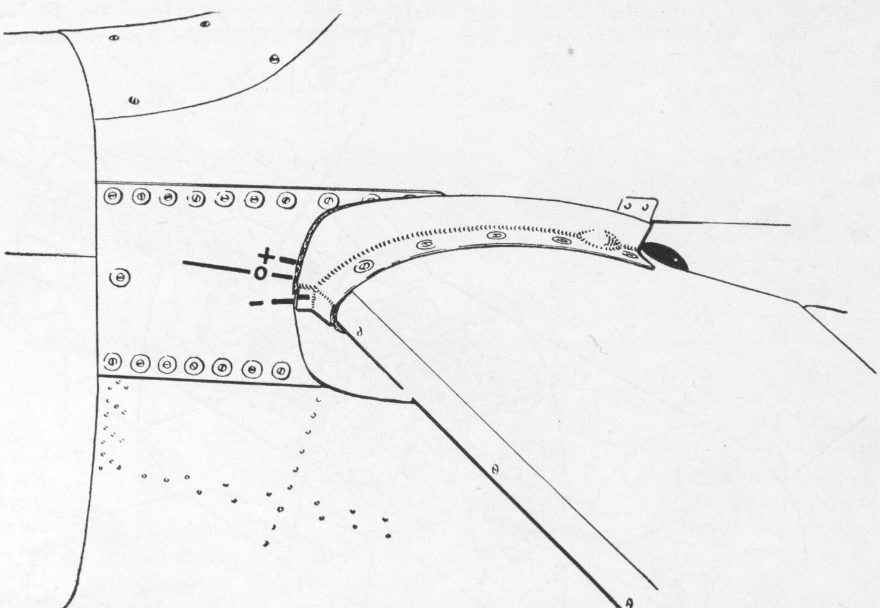


Fig. 6. The stabilizer angle of attack is adjusted by an electric motor-driven screw jack mounted in the L.E. of the vertical fin, with hinge point along the spar at the T.E. An electric indicator is attached to the stabilizer so that its position is shown on the instrument panel. This sketch shows adjustment marks on the fuselage and fairing.

one part of the plane to another in the same location, so that mechanics working on one aircraft will not have to become completely reindoctrinated before being assigned to another make or type.

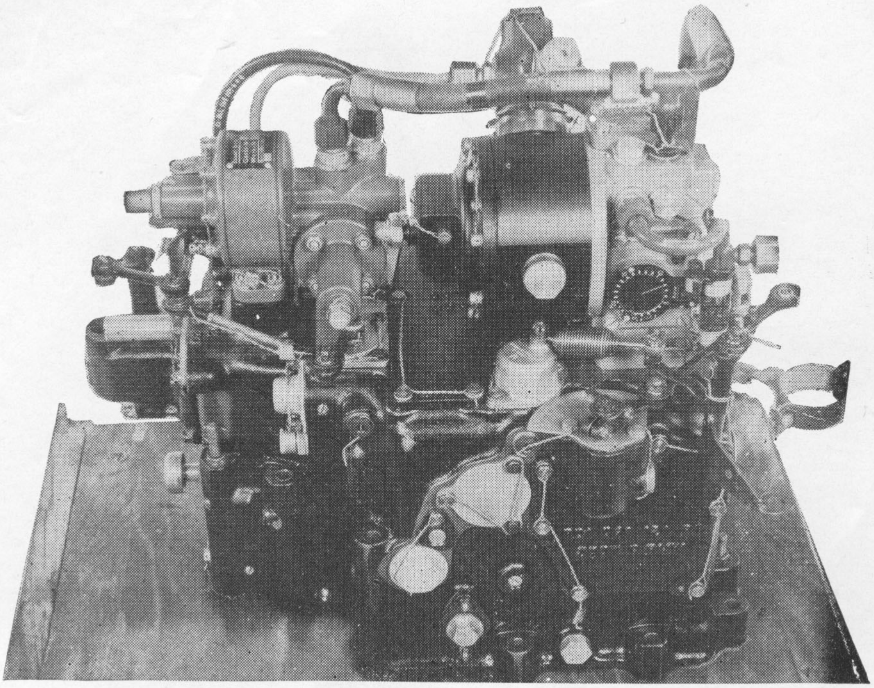


Fig. 7. Here is the Kommandgerat or "brain box." Located just ahead of the engine mount ring, it is connected to the throttle linkage. When the pilot moves the throttle lever, this hydraulic-electric unit automatically adjusts fuel flow, fuel mixture, propeller pitch setting, ignition, and, at proper altitude, cuts in the second stage of the supercharger. It is 16 in. high, 16 in. long, and 12 in. wide.

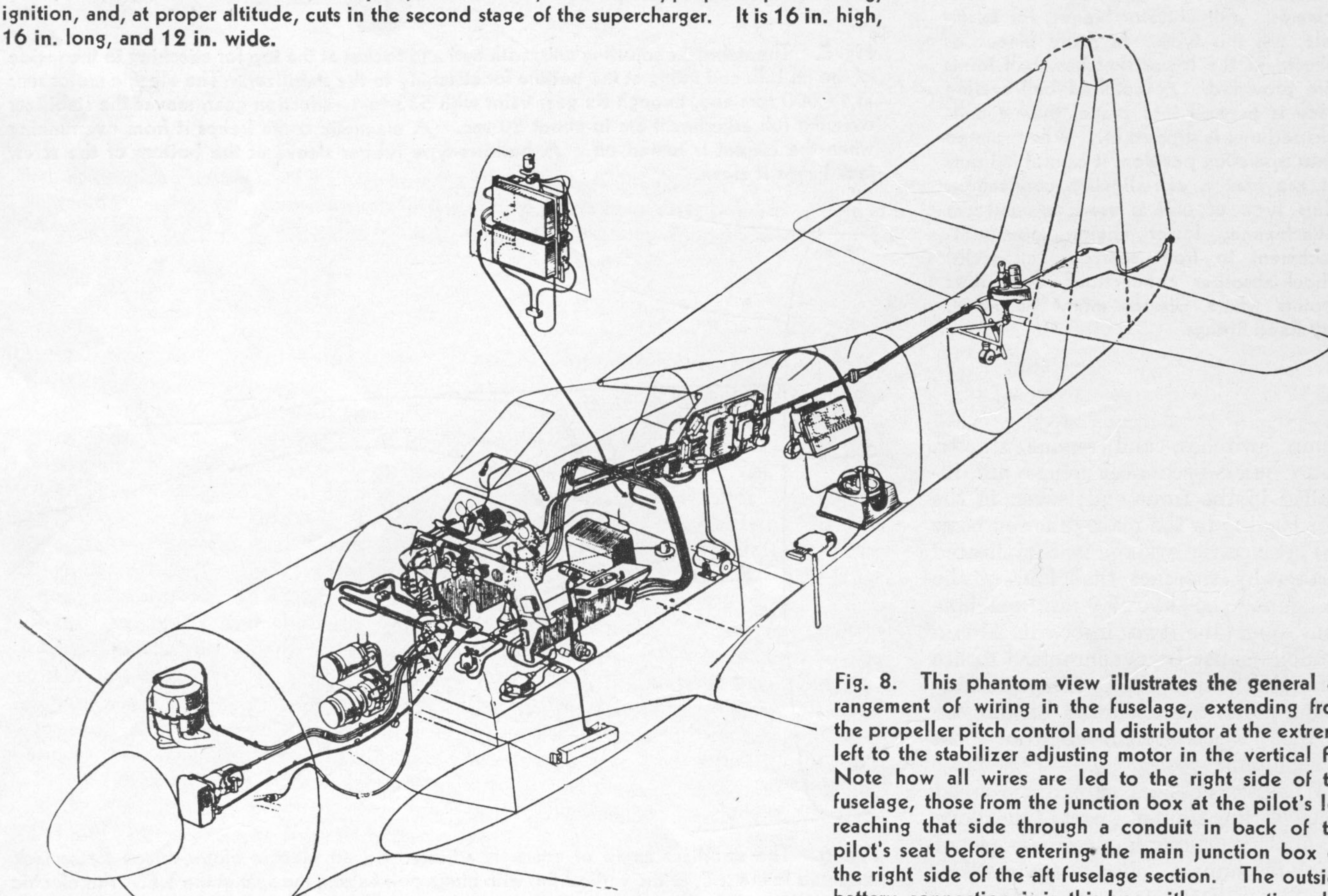


Fig. 8. This phantom view illustrates the general arrangement of wiring in the fuselage, extending from the propeller pitch control and distributor at the extreme left to the stabilizer adjusting motor in the vertical fin. Note how all wires are led to the right side of the fuselage, those from the junction box at the pilot's left reaching that side through a conduit in back of the pilot's seat before entering the main junction box on the right side of the aft fuselage section. The outside battery connection is in this box with connecting plug flush with the fuselage skin.

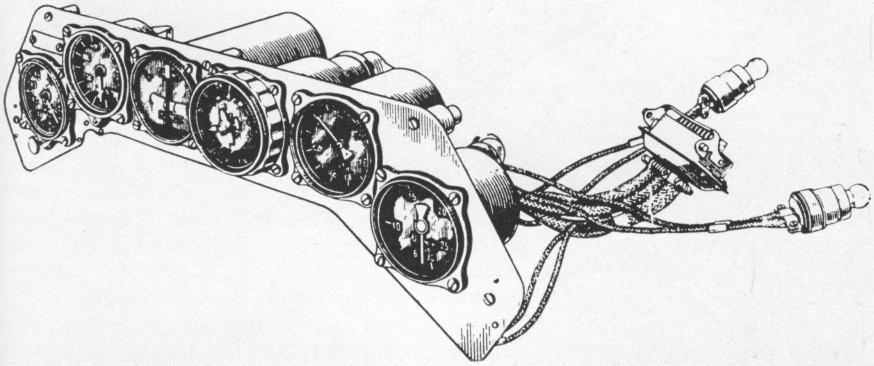


Fig. 9. **Quickly detachable flight instrument panel with, left to right, altimeter, bank-and-turn and air-speed indicators, tachometer, compass, and manifold-pressure gauge. Note the use of quick-disconnect plugs.**

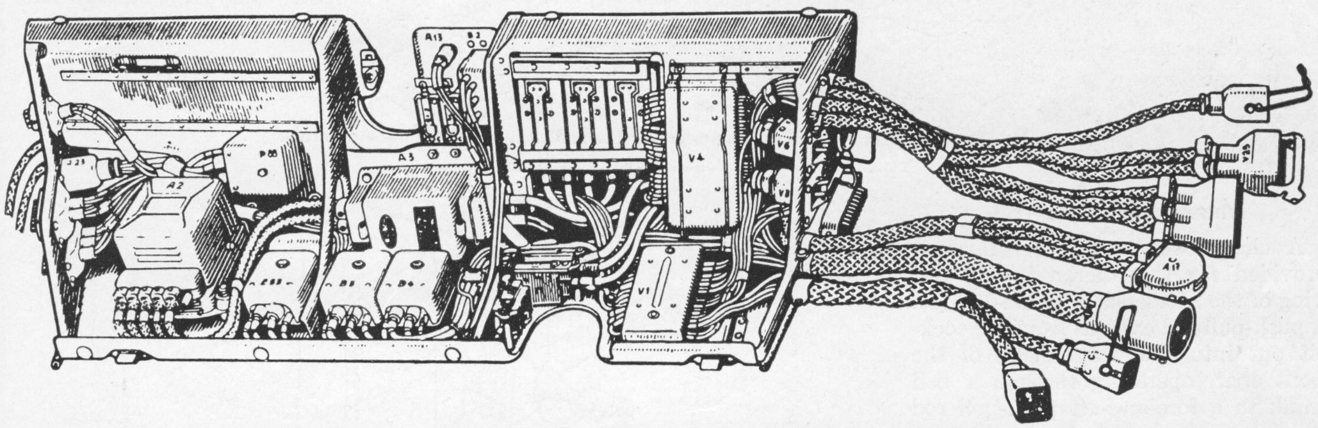


Fig. 10. **Bottom view of the control switch junction box located at the left of the pilot's seat. Note how all lines leading out at the right have been grouped into seven quick-disconnect plugs, each one of which is of different shape so that wrong connections cannot be made.**

Grumman F6F

The Grumman F6F control stick is a forked type (1) operating the ailerons and elevators (2).

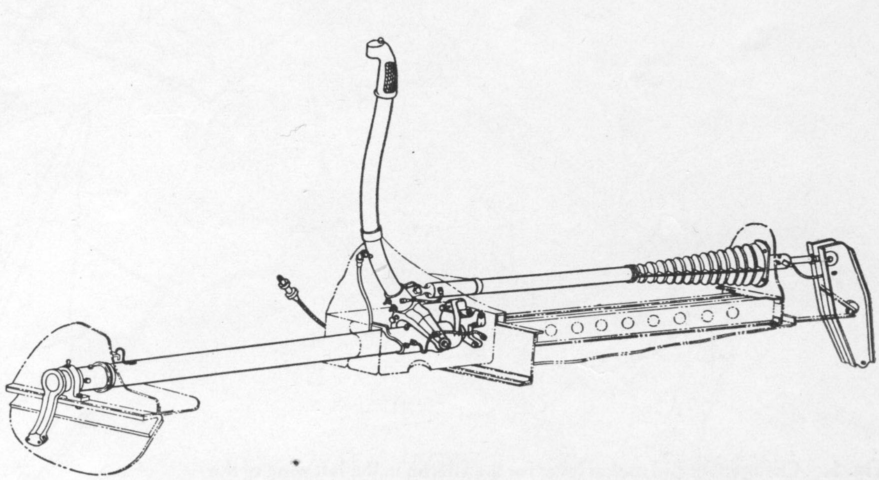


Fig. 1. **Phantom sketch showing the construction and installation of the control stick on an F6F.**

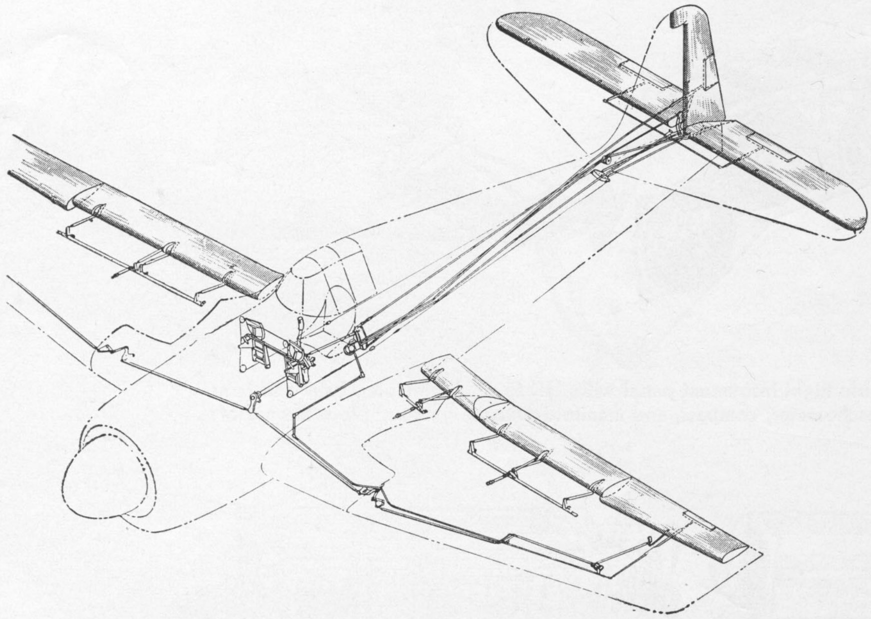


Fig. 2. Phantom view of a Grumman F6F Hellcat showing the surface controls.

Messerschmitt Me-163

A changeover and rocker lever is provided for the aileron in the left wing of the Messerschmitt Me-163 (1). A push-pull rod extends from the cockpit out into the wing ahead of the front spar, operating through a bell crank to a fore-and-aft push-pull rod which goes through the rocker lever.

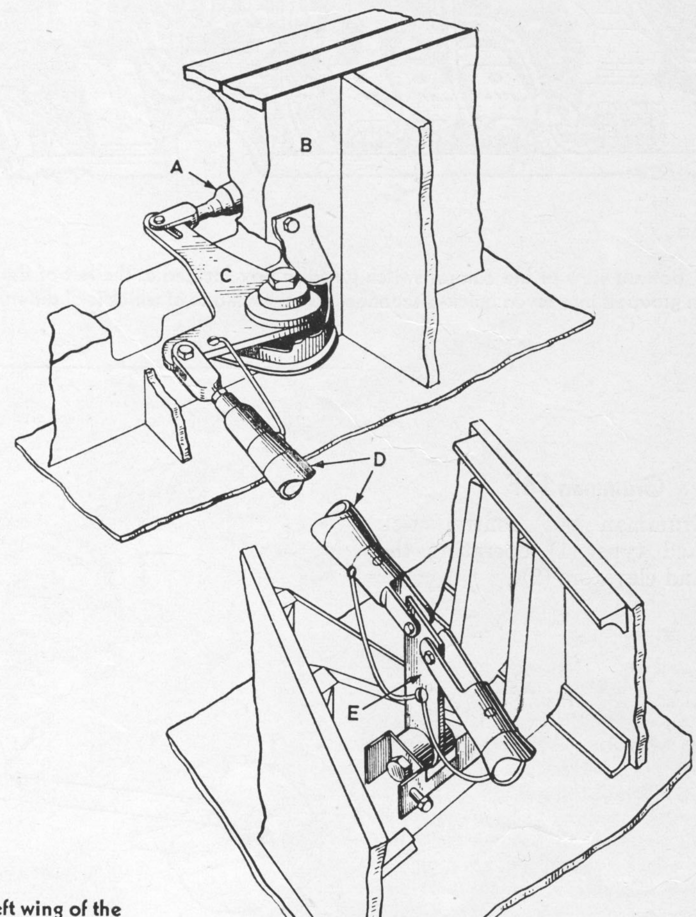


Fig. 1. Changeover and rocker lever for the aileron in the left wing of the Messerschmitt Me-163. Push-pull rod (*A*) from the cockpit extends out into the wing ahead of the front spar (*B*), operating through bell crank (*C*) to a fore-and-aft push-pull rod (*D*), which goes through rocker lever (*E*).

Zeke 32 (Hamp)

Quite a mixture of the old and fairly modern controls is presented by the Hamp. For example, bearings run all the way from the plain to rollers, and the only way to repair some of the units is to replace them completely. In some cases this is no 5-min job, since most units are riveted in place.

The control stick is made up of very light stamping and tubing, and apparently weight saving was the dominant factor in its design.

The aileron control consists of a yoke at the base of the stick with a tube held by two plain bearing brackets running aft under the pilot's seat to a bell crank set just aft of the rear face of the rear spar (1).

Push-pull rods, 1¼ in. in diameter, run from there to bell cranks set in built-up brackets at the center aileron hinges. Idlers to prevent buckling keep the maximum length of the rods to 50 in.

Elevator controls embrace a push-pull rod with rotating thrust bearing extending from the stick back under the pilot's seat to a self-aligning ball-bearing bell crank held by brackets attached to the rear spar, with a torque tube extending out to bell cranks held by brackets riveted to the rear spar at the cockpit sides. These brackets have a built-in stop block to prevent pushing the stick too far forward and a cable stop limiting its backward motion.

Pivots of the bell cranks are set about 1 in. ahead of the spanwise tube, so that the cranks move up and down as the stick is moved. Quarter-inch cables extend from these cranks back through four different types of fair-leads (2) to the elevator horn.

The rudder control design is best described by the word "obsolete." Cables are attached to a diamond-shaped plate, with the usual lightening holes, reinforced by riveted flanges, the whole unit being set in a bracket attached to the top wing skin which forms the cockpit floor (4).

Atop the plates are riveted two tubes and a screw jack, on the aft end of which is a six-spoke wheel to give pedals a 4-in. fore-and-aft adjustment. The rudder bar is simply a bent alloy tube welded to brackets fitting over the tubes, and pedals are riveted to lugs welded to the outer ends of the bar.

The hydraulic system is used only for the landing gear and flaps and is,

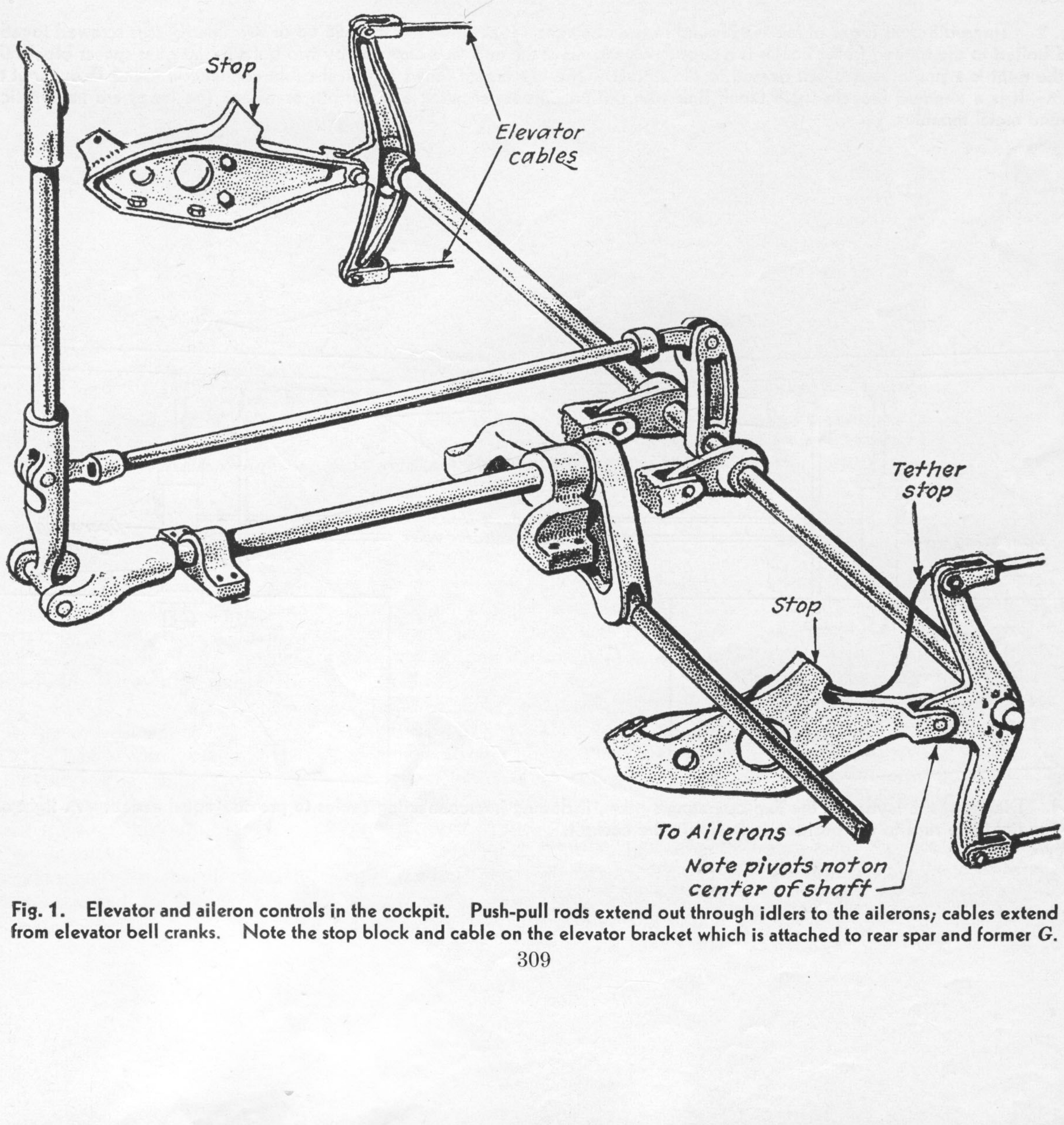


Fig. 1. Elevator and aileron controls in the cockpit. Push-pull rods extend out through idlers to the ailerons; cables extend from elevator bell cranks. Note the stop block and cable on the elevator bracket which is attached to rear spar and former *G*.

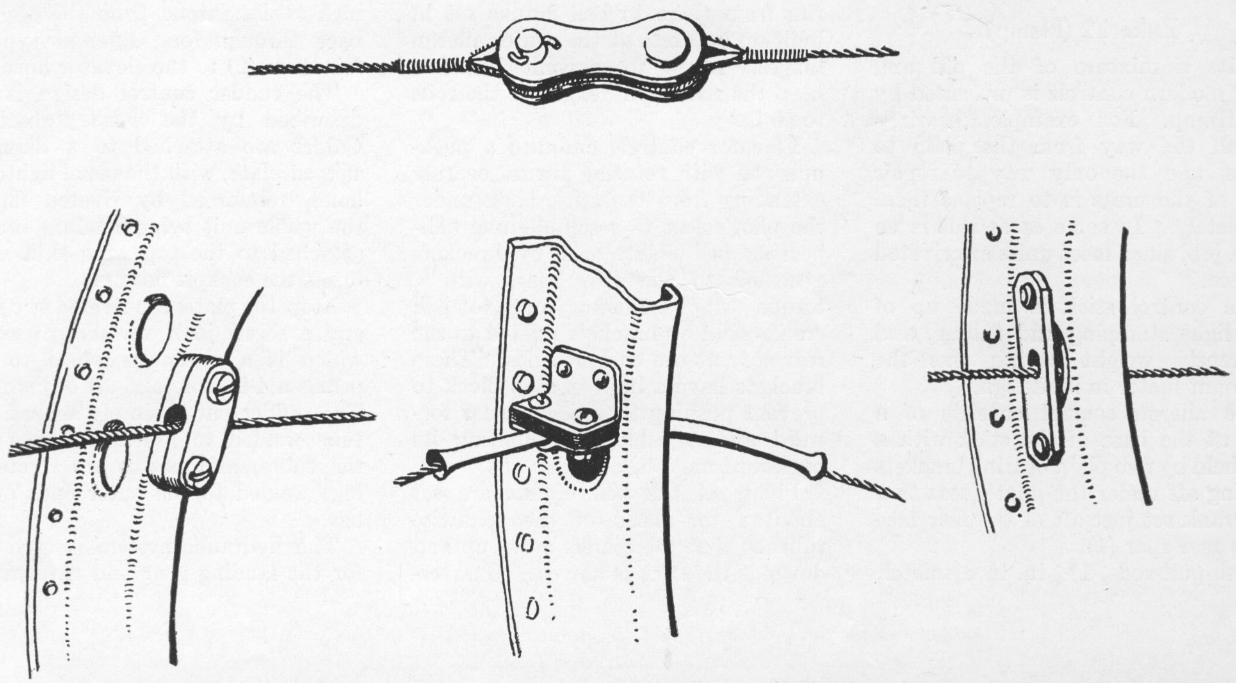


Fig. 2. Three different types of fair-lead found in the fuselage. That at the left is made up of two fiber blocks screwed together and bolted to the former; in the center is a copper tube flared at the ends and clamped by two bolts to the fiber spacer block; that at the right is a single fiber block riveted to the former. The top sketch shows a typical cable connection found throughout the craft. It is a standard bicycle-chain repair link with drilled pins for securing a cotter pin or wire. The loops are hand-spliced around metal thimbles.

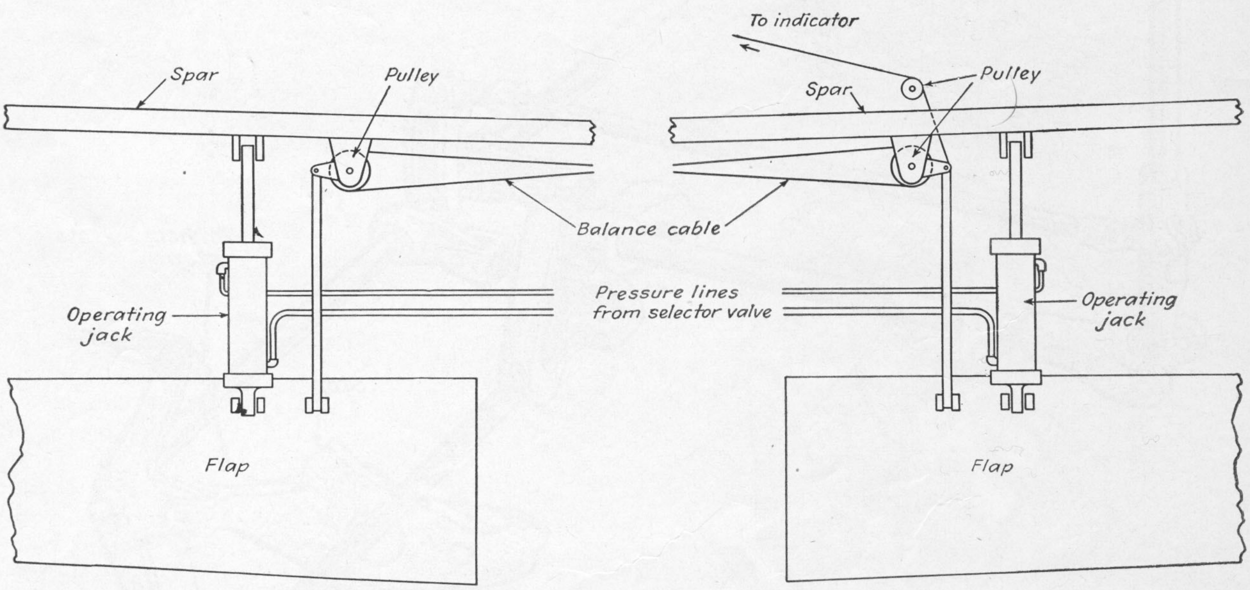


Fig. 3. Diagrammatic layout of the flap-operating system, including interconnecting cables to provide equal action. A light cable from the right flap runs to the position indicator in the cockpit.

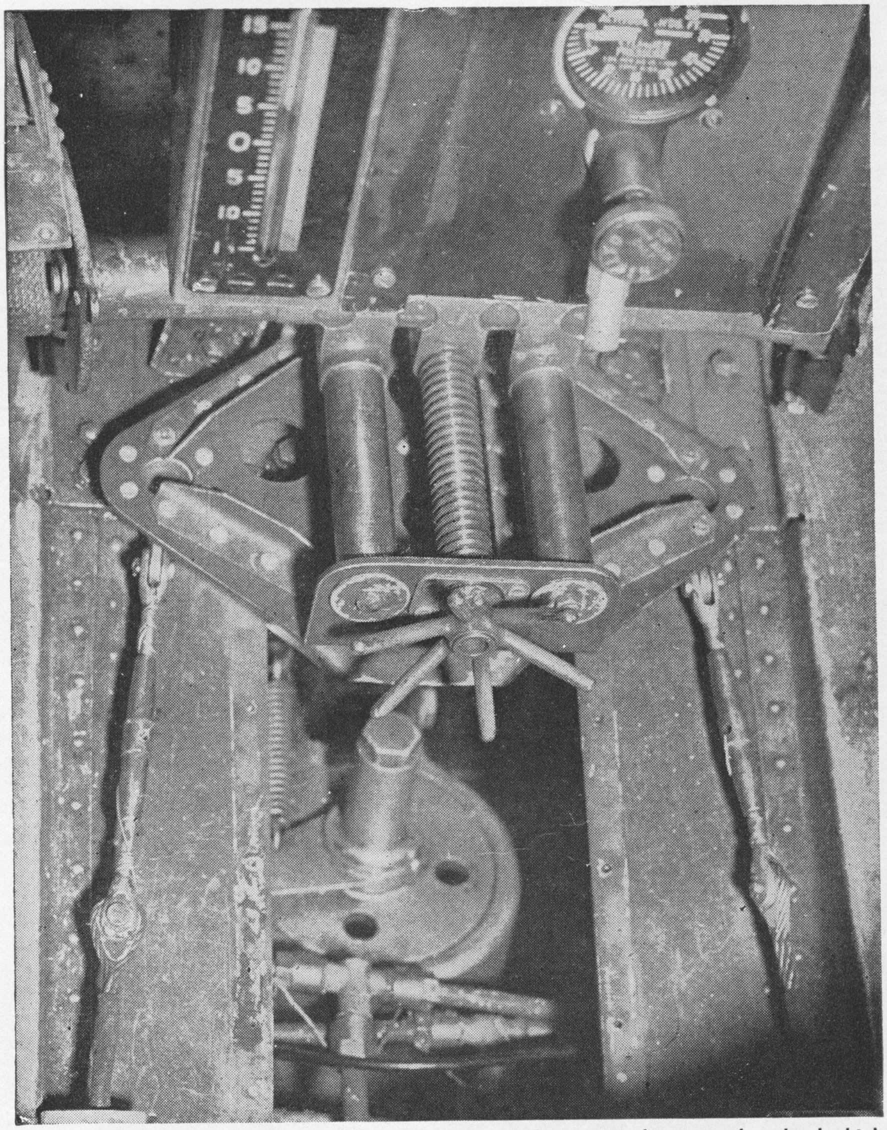


Fig. 4. Fore-and-aft adjustment of the rudders is made by turning this six-spoke wheel which turns a screw to move the entire rudder bar, a simple bent tube welded to a bracket attached to a diamond-shaped plate which contains typical lightening holes.

therefore, a fairly simple unit. Pressure is supplied by a small gear-type pump driven by a gear train from the engine and is regulated by a spring-loaded regulator valve adjustable between 782 and 853 psi. Excess pressure is by-passed through the valve into the 5¼-pt reservoir located in the fuselage behind the pilot. No accumulator is provided, pressure depending entirely on the pump.

The flap-operating hydraulic cylinder is attached to the flap, with the piston attached to the spar. A bracket attached to the cylinder connects with a cable to the other flap, ensuring equalized operation (5).

A light cable from the right flap runs to a position indicator in the cockpit (3).

Landing gear operating control is provided with a safety-lock pin (6) attached to the right wheel, so that when the plane is on the ground and the oleo is shortened by weight, this pin is forced out behind the gear selector so that it cannot be moved and landing gear retracted. The arrestor gear operating crank and ratchet are provided with a clip spring which holds the handle in position (7).

Light weight is again apparent in the two-wire electric system, current for which is supplied by an engine-driven generator and a 12-volt 20-amp battery. Switches are simple but rugged; light wiring is used throughout, and conduits are small.

It is interesting to note here that in many places throughout the craft, conduits, wires, and plumbing are not held in place by brackets, but simply by shellacked tape tied into lightening holes found practically any place.

(a)

(b)

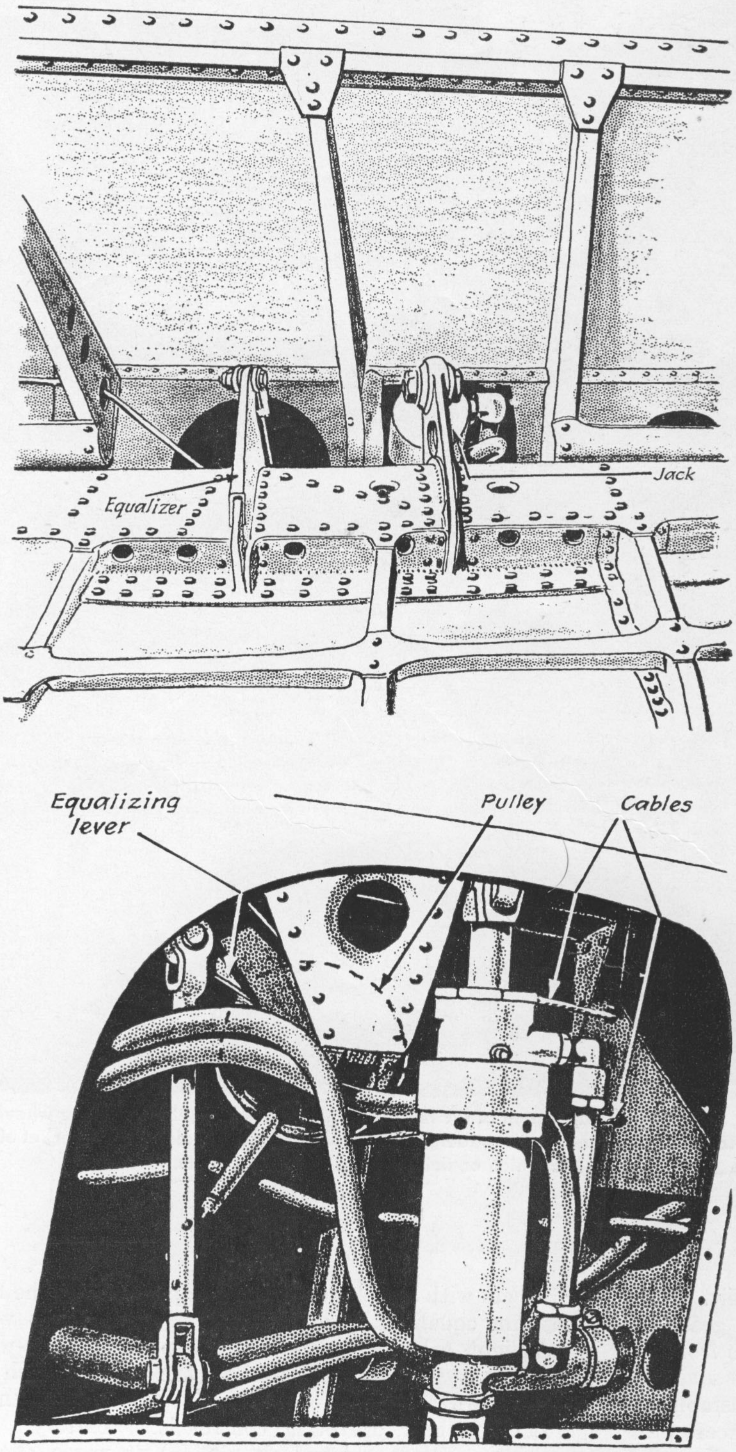


Fig. 5. View from beneath the wing T.E. (*a*) showing the installation of the flap-operating hydraulic cylinder, which is attached to the flap with piston attached to spar—and bracket (left) to which is attached a cable connected with the other flap to ensure equalized operation. Detail (*b*) is a phantom view through the top of the wing, showing the installation of the operating cylinder.

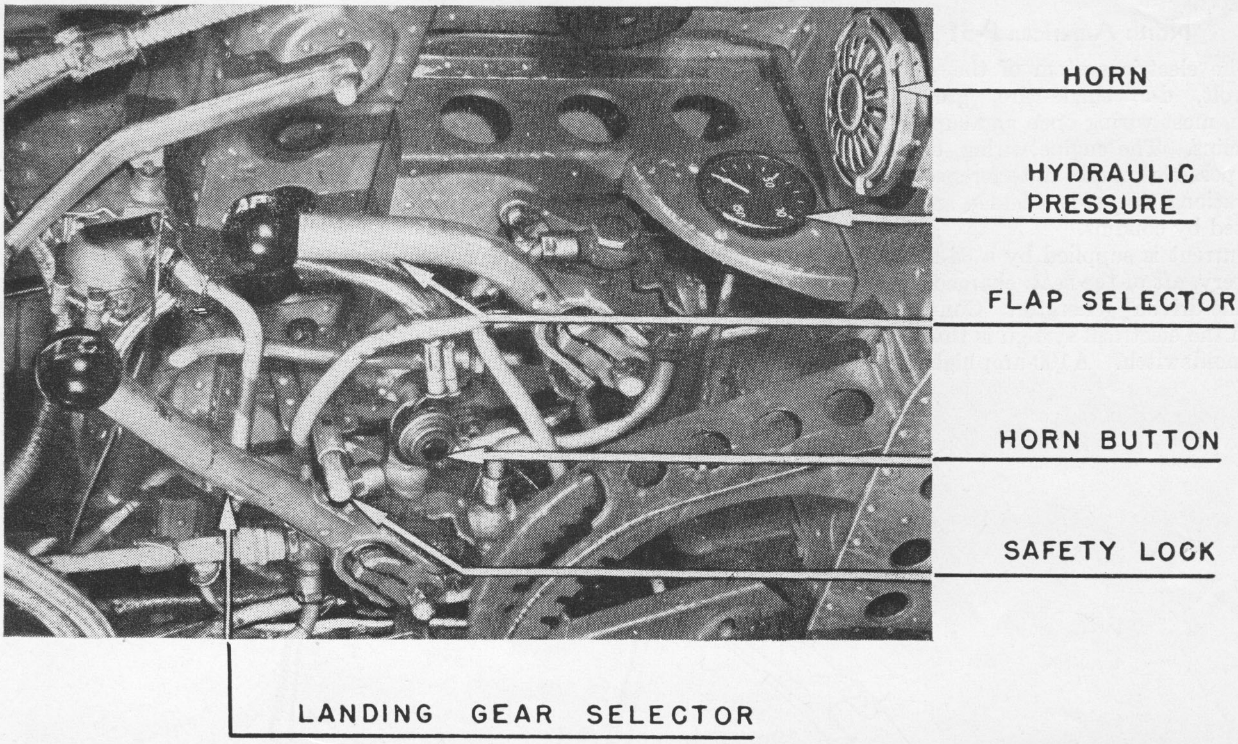


Fig. 6. Landing gear operating control, showing a safety-lock pin. Attached to the right wheel so that when the craft is on the ground and the oleo is shortened by weight, this pin is forced out behind the gear selector so that it cannot be moved and landing gear retracted. A warning horn blows if the pilot does not return the selector to neutral position after the wheels have been retracted and locked; it does not blow if he forgets to lower the wheels when coming in for a landing. Teeth on the quadrant for vertical adjustment of the pilot's seat are seen in the lower foreground.

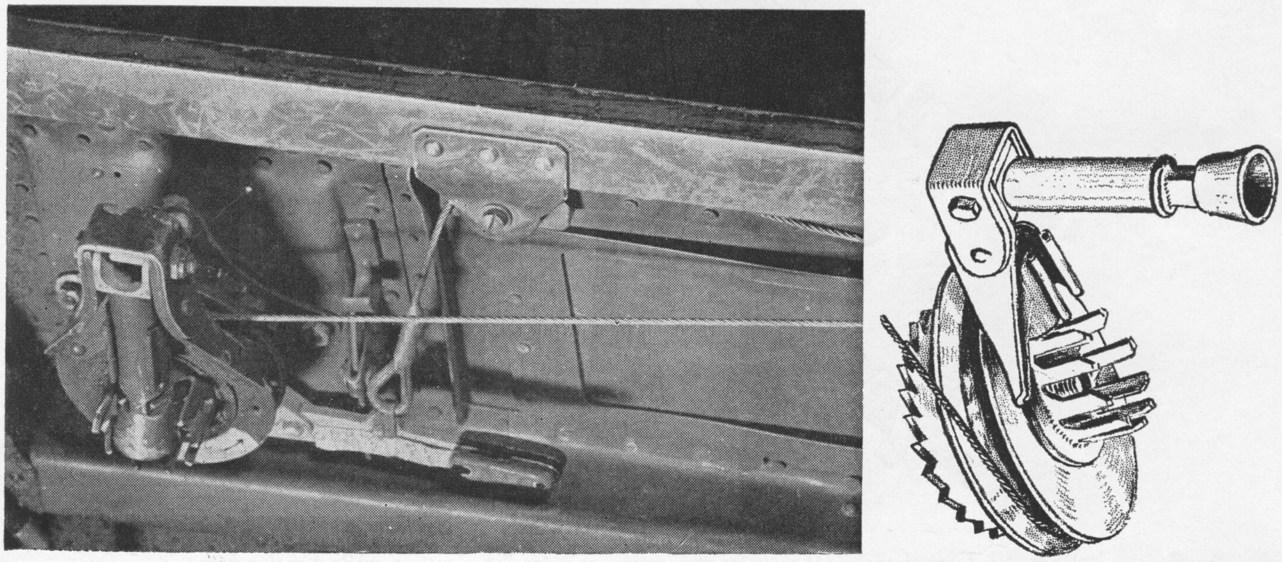


Fig. 7. Arrester gear operating crank and ratchet, shown in closed and locked position in the photograph, with a clip spring holding the handle in locked position. With handle extended to operating position the sketch shows the radial ratchet which forms a nut to hold the pulley and ratchet in place.

North American P-51

The electric system of the P-51 is 24-volt, d-c, single-wire, grounded-type, most wiring open and supported by clips. The engine wiring, because of possible radio interference and vibrational stress, is shielded and supported by conduit.

Current is supplied by a 34-amp-hr battery, aft of the seat, charged by an engine-driven generator. Connection with the electrical system is through a solenoid switch. A 100-amp high-speed generator supplies current through a relay, which serves a generator cutout. A voltage regulator maintains potential at 28.

Radio equipment consists of sets for communication with other aircraft or ground. The antenna is a fore-and-aft, vertical mast type. Receivers and transmitters are aft of the seat.

The center section of the control stick (1) operates the elevators, while a rocker with forked ends moves the ailerons. Elevator and elevator tab controls are by cable from the cockpit (2). Aileron trim tabs are controlled from the cockpit by a knob (4). Cable travel is restricted by stops, and adjustments are made by means of turnbuckles. A rear-wheel steering mechanism is included in the rudder controls.

Among the engine controls are engine throttle, throttle stop release; adjustable throttle stop, quadrant to bell-crank flexible control, fair-leads, propeller control bracket and bell crank, emergency boost control, carburetor-air control, hot-air control (3).

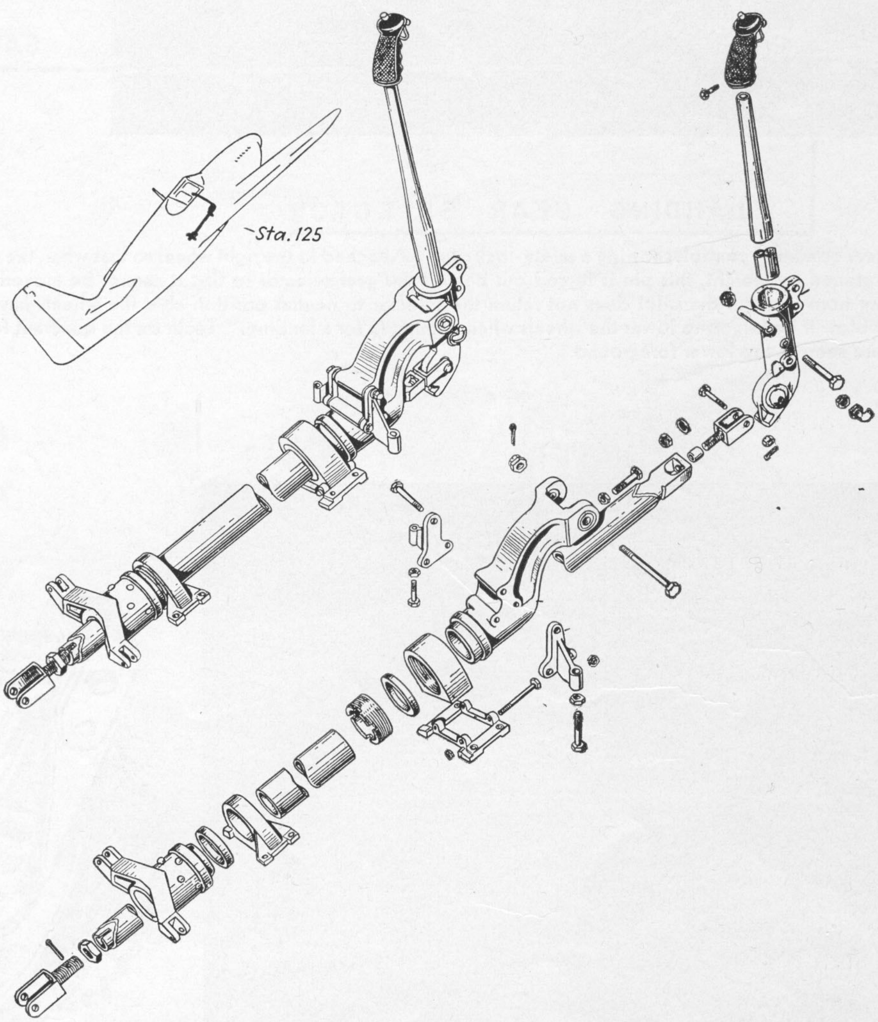


Fig. 1. Control stick. The center connection operates the elevators, while a rocker with forked ends moves the ailerons.

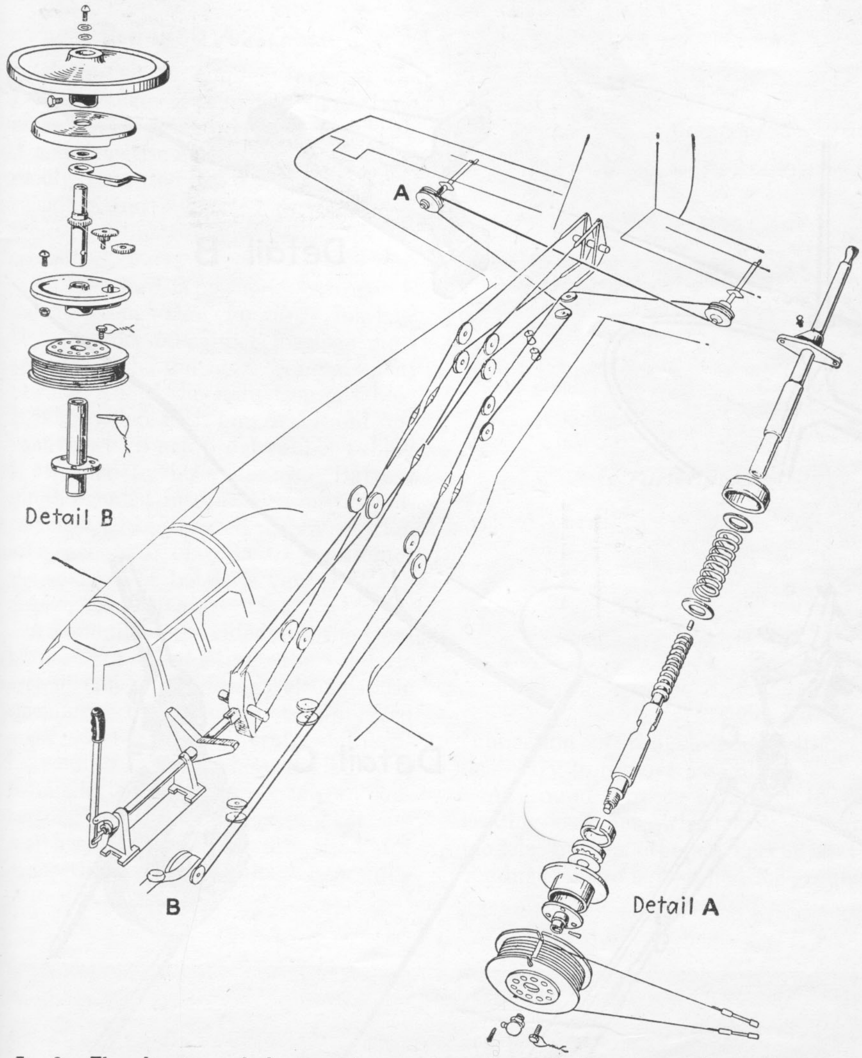


Fig. 2. The elevator and elevator tab controls are by cable from the cockpit. Tab rear controls are detailed at *A*. The cable to the tabs is operated by a handwheel, to which is connected an indicator driven by small gears, as shown in detail *B*.

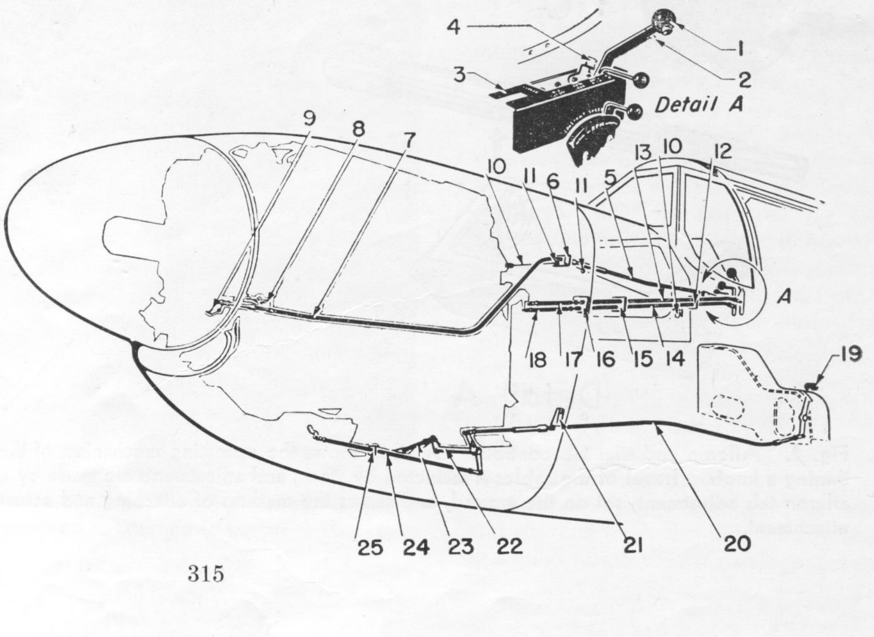


Fig. 3. Engine controls: (1) engine throttle control; (2) throttle stop release, (3) throttle name plate; (4) adjustable throttle stop; (5) quadrant to bell-crank flexible control; (6), (11), (12), (15), (16), (25) fair-leads; (7) flexible control; (8) propeller control bracket; (9) propeller control bell crank; (10) emergency boost control handle; (13), (14), (17), (18) control rods to jackshaft; (19) carburetor air control; (20) flexible air control; (21) air control support; (22) jackshaft, hot-air control; (23) hot-air door-actuating rod; (24) air shutoff control rod; (25) shutoff rod support.

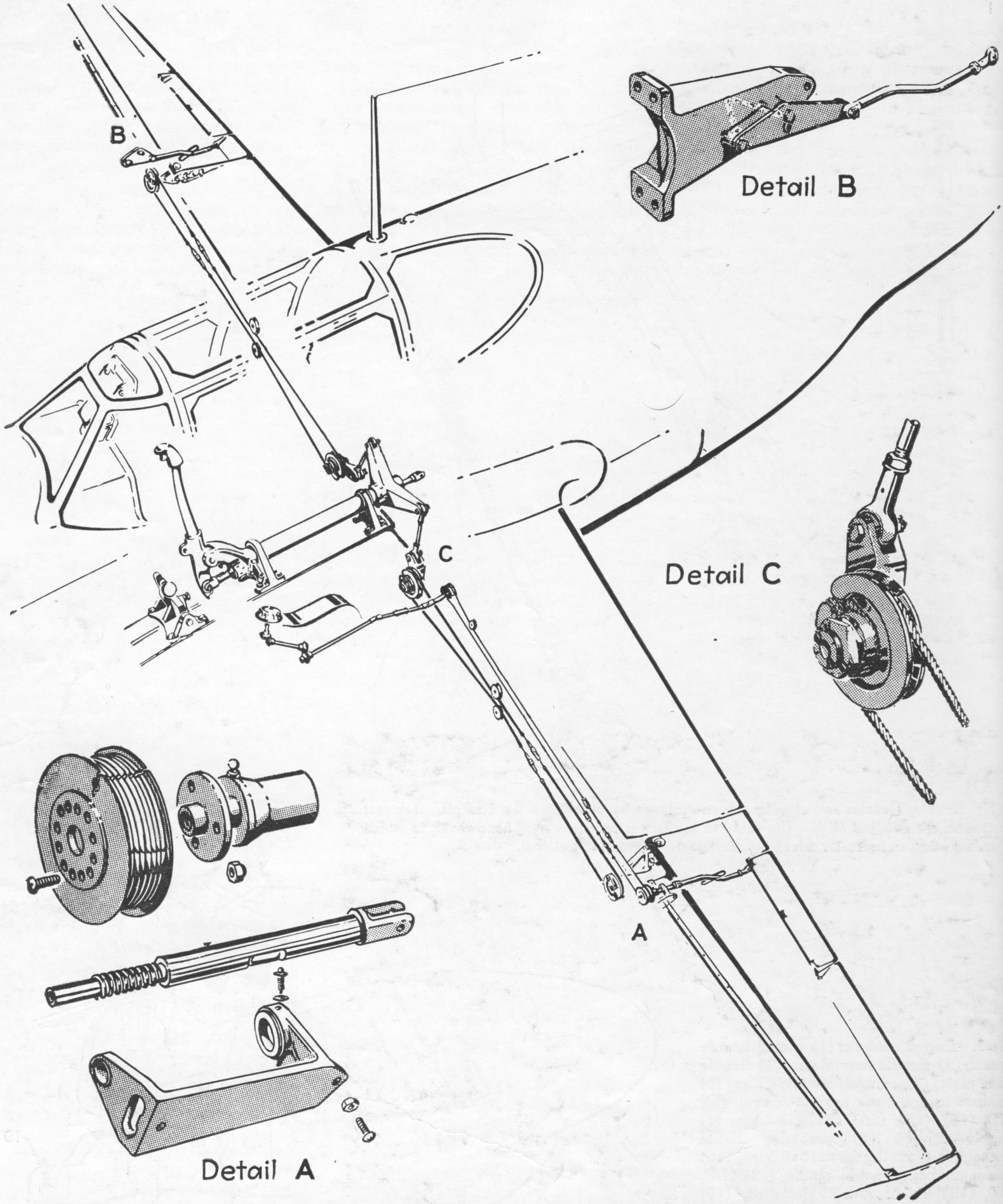


Fig. 4. Aileron and trim tab controls. Detail *A* shows the operating mechanism of the left-hand tab, controlled from the cockpit by turning a knob. Travel of the cables is restricted by stops, and adjustments are made by means of turnbuckles. *B* is a detail of the right aileron tab adjustment, set on the ground, and shows the method of attaching and actuating the aileron cables by a link from the stick attachment.

Bell P-39 Airacobra

Of the single conductor type, the P-39's electric system is shielded and protected by rigid and flexible conduits. A main electric control switch panel is rigidly mounted to a metal box for shielding and is located to the left of the main instrument panel in the cockpit.

A standard-type a-c battery is mounted in the forward fuselage between the .50-caliber fuselage guns and beneath the gun compartment cowling, aft of the reduction gearbox. It is provided with one drain and one vent to which acidproof rubber tubing is attached by hose clamps. Battery fumes exhaust into a glass bottle containing a pad saturated with a solution of bicarbonate of soda to counteract the acid. The bottle is vented to the airplane slip stream.

A conduit is provided for the dual purpose of protecting the electric system and providing electrostatic shielding. Rigid conduit is supported and grounded to the aircraft, and flexible conduit is used where flexibility is required. Standard-type plugs, connectors, connector plugs, socket assemblies, and fittings are used for connecting the conduit where disconnection of the electric system is necessary to remove assemblies.

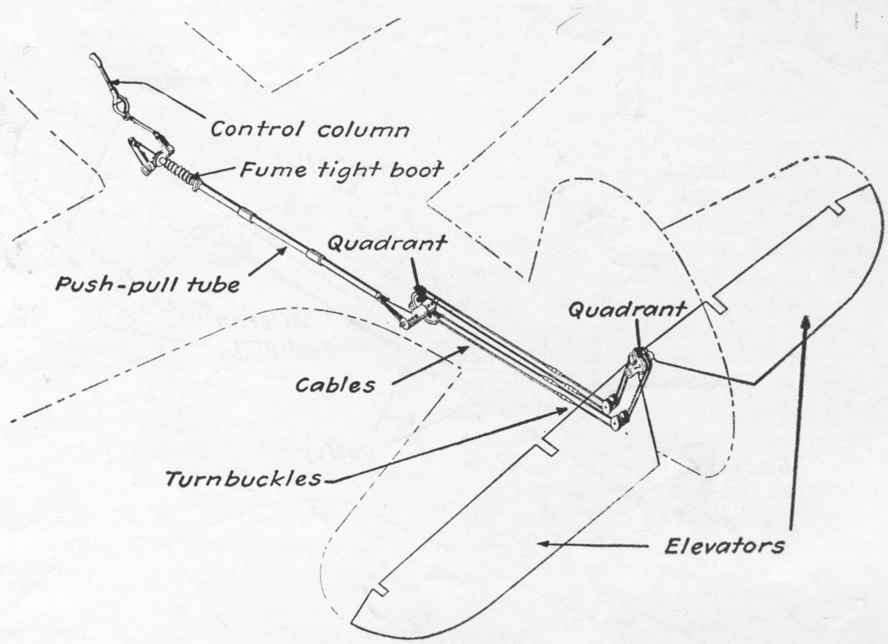


Fig. 1. Elevator control system.

A ground wire is attached to the landing gear nose-wheel fork on some models, but on others a special static conducting tire is installed for grounding purposes. The main fuse panel is located on the left side of the landing gear nose-wheel well within the forward fuselage. Fuse capacity and identification are marked inside the box lid, and spare fuses are carried in the fuse box.

The P-39's control system is of the stick type, the control column attached to a yoke at the cockpit floor through which the engine-drive shaft runs from behind the pilot to the propeller reduction gearbox.

Control column travel is regulated by four stop bolts, two of which are located so that they contact the aileron lever (regulating lateral movement), and two are located to contact the yoke bottom (regulating fore-and-aft movement).

The rudder pedals are adjustable in five positions ranging from $3\frac{1}{4}$ in. forward to $3\frac{1}{4}$ in. aft of the 90-deg setting. They are adjusted by two levers, one located outboard of each pedal. These foot-operated levers are spring-loaded and release a pin from a stop when depressed. The main control cables are constructed of extra-flexible corrosion-resistant steel, and the control cable pulleys are of the antifriction ball-bearing type.

Control of the elevators is through a push-pull tube assembly attached to the bottom of the control column yoke and running back through the fuselage to a quadrant in the aft fuselage section

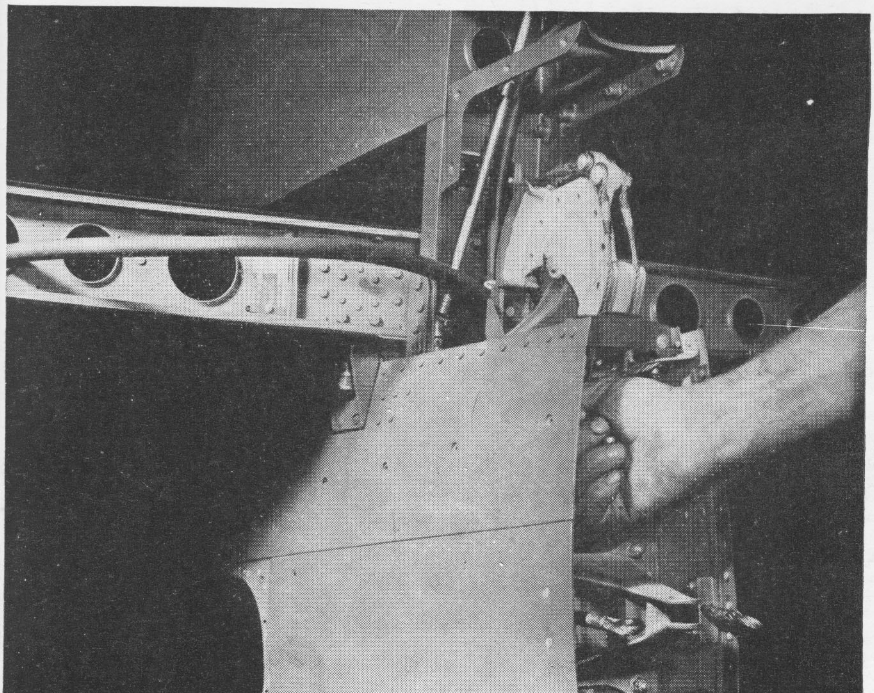


Fig. 2. The control quadrant for operating the elevators is attached to the aft fuselage just behind the horizontal and vertical stabilizers.

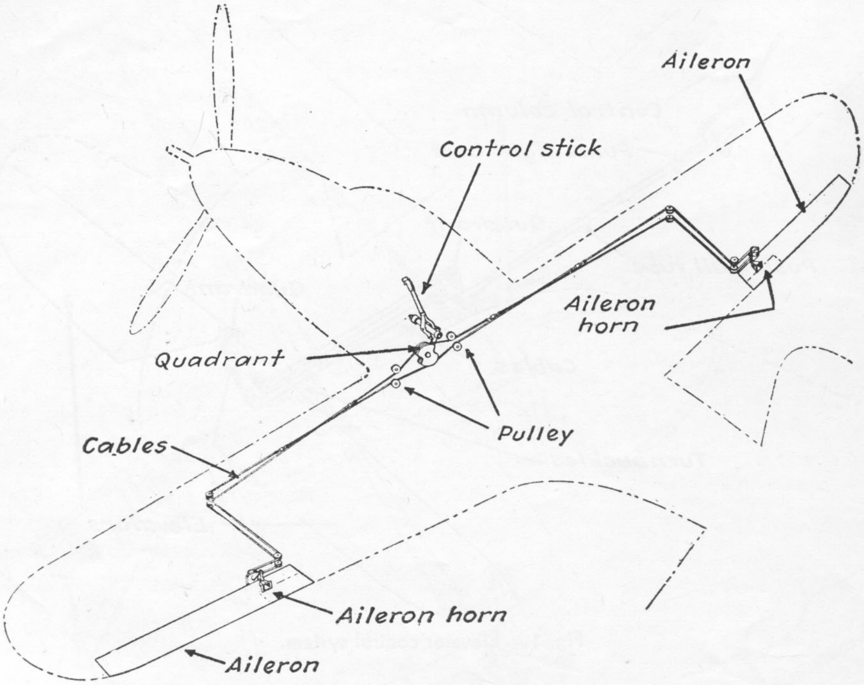


Fig. 3. Aileron control system.

(1). From this point, a duplicate cable system (four cables in all) extends along the aft fuselage, around a set of pulleys at the extreme rear, and upward to the elevator control quadrant (2) at the elevator splice bar.

The aileron lever on the control column actuates an aileron link rod connected to a quadrant in the fuselage (3). Control cables run outboard from this quadrant along the leading edge of each outer wing panel. At wing station 7.5, the cables make a 90-deg turn aft and run to a quadrant located on the forward side of the wing auxiliary beam. The quadrant actuates a linkage assembly that connects to a fitting on the aileron L.E.

Two link rods connecting the rudder pedals to two quadrants in the center section of the fuselage form the rudder control (4). Control cables are connected to these quadrants and extend aft through the fuselage, guided and supported by pulleys, to the rudder control quadrant on the rudder main beam.

Flaps are actuated by a ½-hp electric motor (5), located on the fuselage deck underneath the right wing fillet and controlled by a toggle switch in the cockpit.

The motor operates two sprocket housings, one located immediately inboard of each wing splice. The right-hand sprocket housing is connected directly to the motor assembly by means of a drive shaft running through the fuselage. The sprocket housing is attached on the outboard side to the flap mechanism consisting of a universal joint, a housing, a screw, a push-pull tube, and five turnbuckles.

The universal joint attaches to a splined shaft of the sprocket housing and connects to the screw assembly which operates the push-pull tube. This tube rolls along on five roller assemblies attached to the wing auxiliary beam. Turnbuckles form the connecting links between the push-pull tube and the flap.

Limit switches stop the flap motor when the flaps are completely up or down. If the switches fail to work, a friction clutch, which is part of the motor and adjusted to slip at an output torque, at slow speed shaft, of 110 in.-lb, will stop the motor.

There are trim tabs on each aileron, the rudder, and the left elevator. Separate control knobs for all three

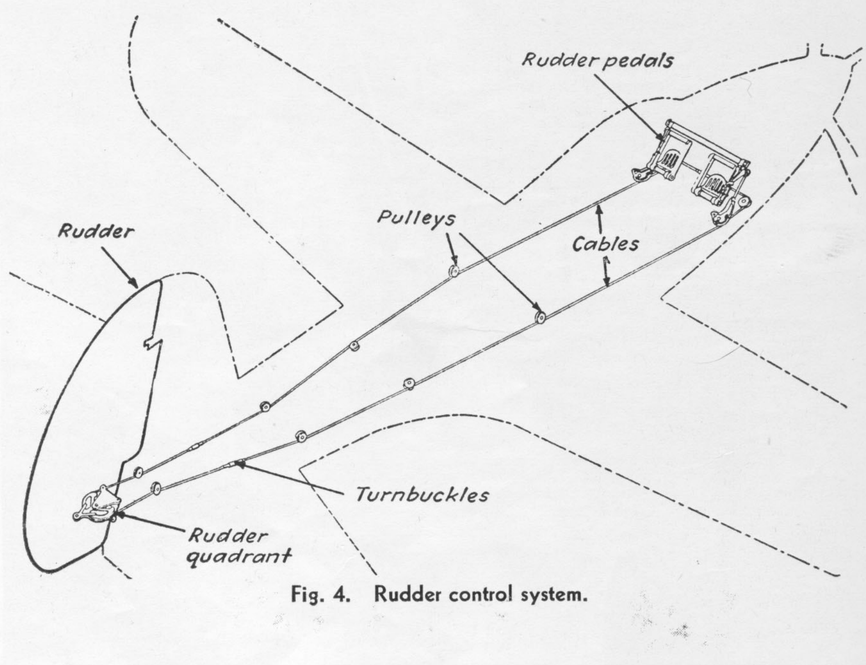


Fig. 4. Rudder control system.

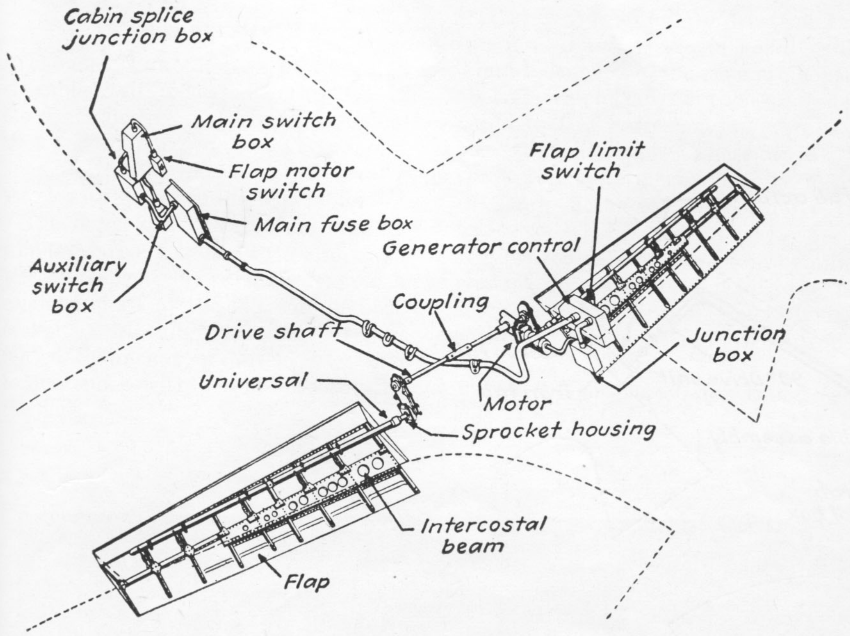


Fig. 5. Landing flap controls powered by a $\frac{1}{2}$-hp electric motor.

are located on the cockpit floor to left of the pilot seat, and each is marked in degrees.

A sprocket-driven chain from the elevator trim control unit (6) is connected by turnbuckles to control cables which are supported by pulleys and run aft through the fuselage. The cables are connected to a straight drive unit. A flexible drive shaft runs from the straight drive unit to the trim tab actuator installed on the left-hand elevator beam.

A sprocket-driven chain, connecting to control cables at the wing L.E., is connected to the aileron trim control (7). Cables run outboard in the L.E. of each outer wing panel to wing station 7.5 where they make a 90-deg turn and continue to the wing auxiliary beam. At this point, cables attach to a chain which operates a sprocket drive unit mounted on the forward side of the auxiliary beam. A flexible drive shaft connects the sprocket drive unit to the actuator mounted on the aileron main beam.

A sprocket-driven chain runs from the rudder trim control (8) to a point just aft of the fuselage turnover beam where it is connected to control cables which run aft through the fuselage and connect to a chain in the aft fuselage.

This chain actuates a 90-deg drive unit which connects to the trim tab actuator on the aft face of the rudder beam through a flexible drive shaft.

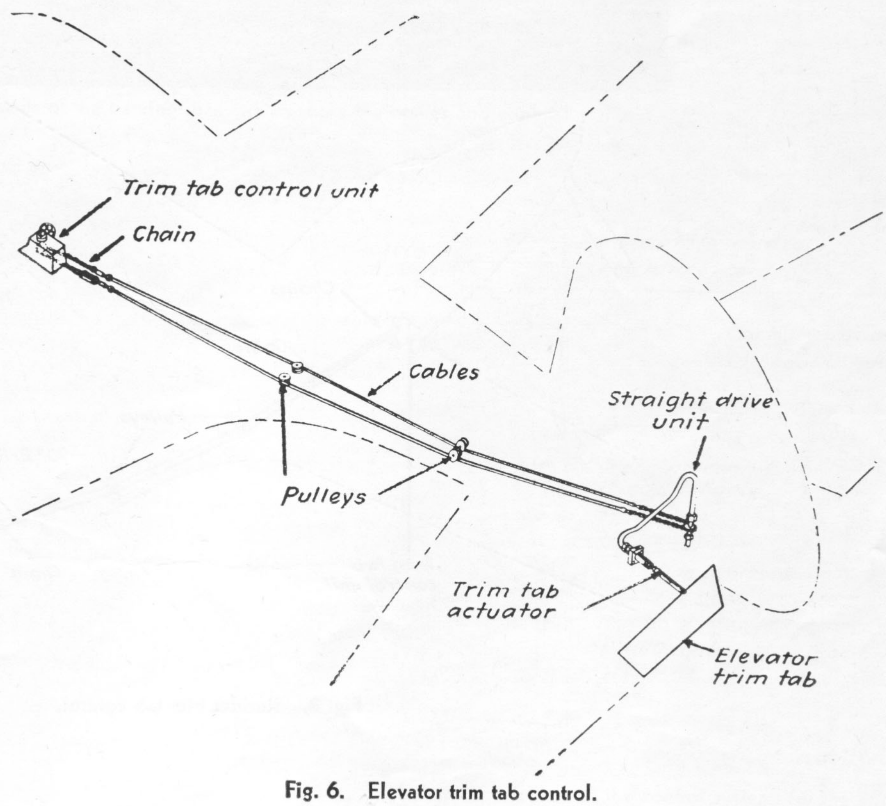


Fig. 6. Elevator trim tab control.

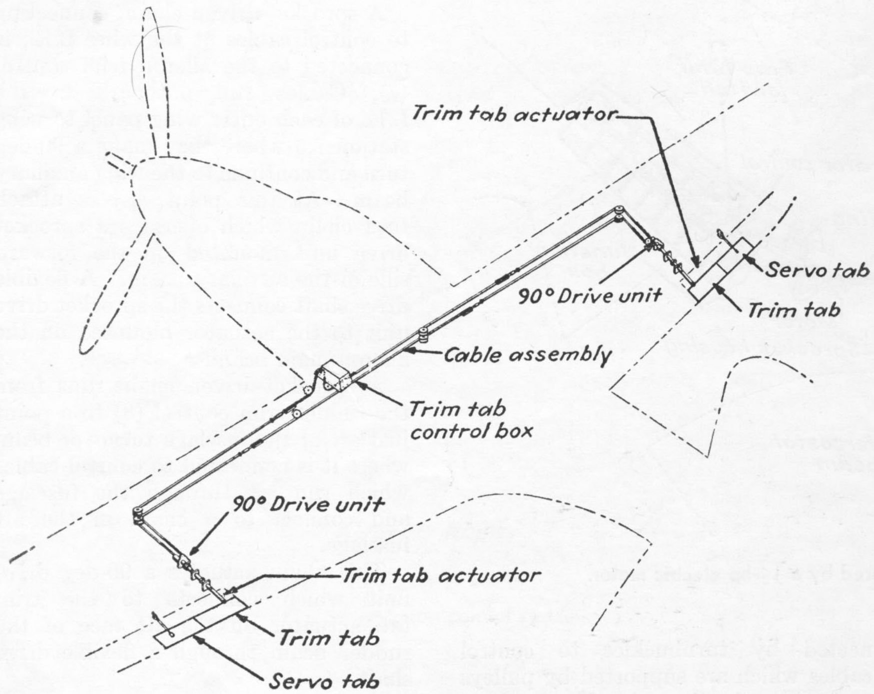


Fig. 7. Aileron trim tab control.

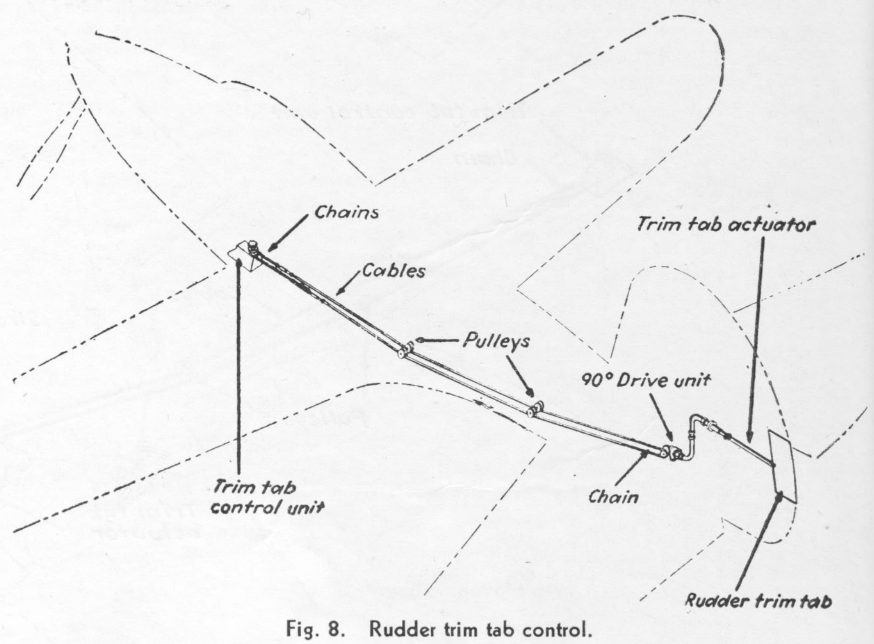


Fig. 8. Rudder trim tab control.

Fleetwings BT-12

The elevators, ailerons, rudder, and steerable tail wheel of the BT-12 are controlled by a conventional dual stick and rudder pedals. The ailerons are actuated by rods and bell cranks; the elevators and rudder by cable.

The flaps and elevator and rudder trim tabs are controlled by a crank and wheels, respectively, arranged about a common shaft at the left side of both cockpits. Motion to the flaps is transmitted by means of miter gears and torque tubes with screw actuators at the flaps.

The elevator and rudder trim tabs are moved by means of small cable-wound drums on the cockpit control shelves, which transmit their motion by cable to two corresponding drums in the aircraft's tail. These turn the shaft and gear mechanism by means of screw actuators which move the tabs.

Elevator cables fasten to a common control horn mounted below the fin. Both elevator torque shafts fit into sockets at this point and are controlled as one.

The rudder has 30-deg travel each side of neutral.

Brakes and controls may be locked by a parking lock (1).

A type B-24 engine control unit is in the front cockpit, and a type B-21 is in the rear cockpit (2).

The electric system is a single-wire grounded return type, except where a two-wire parallel return system is necessary to eliminate magnetic effect on the compass. A type D-6A battery is in the fore fuselage behind the engine. The Eclipse E5A generator has a maximum output of 50 amp at 15 volts.

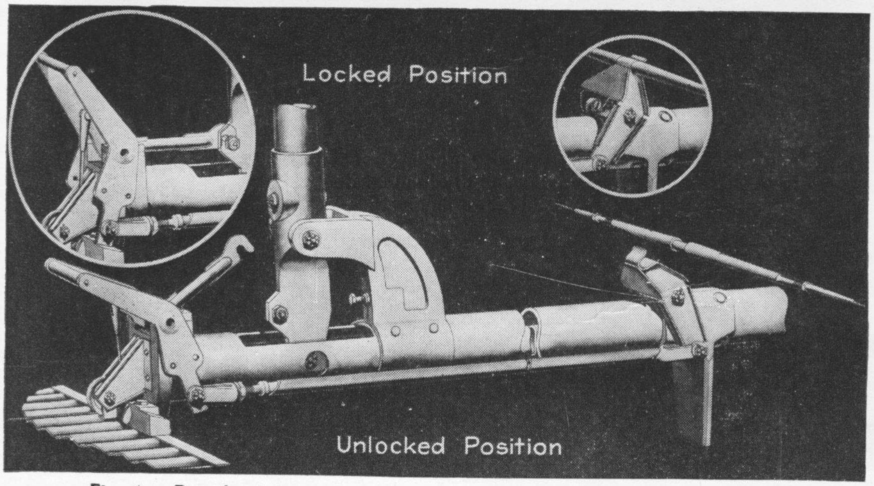


Fig. 1. Details of the parking lock, which locks the brakes and controls.

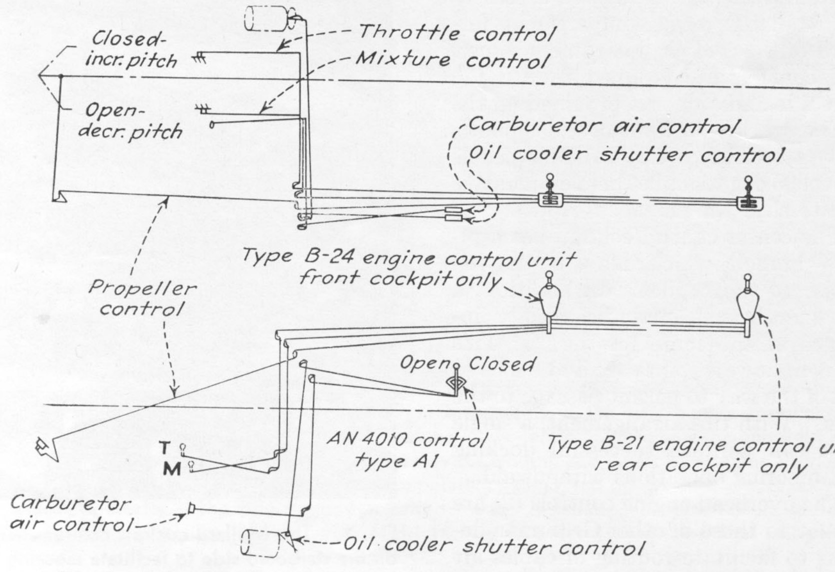


Fig. 2. Schematic diagram of the control systems for the engine and propeller.

Republic P-47N

The P-47N elevator control includes an adjustable stop nut set in a fitting attached to a torque tube; the distance from the fitting determines the limit. A rudder stop nut is set in a fitting attached to the rudder hinge bracket (1).

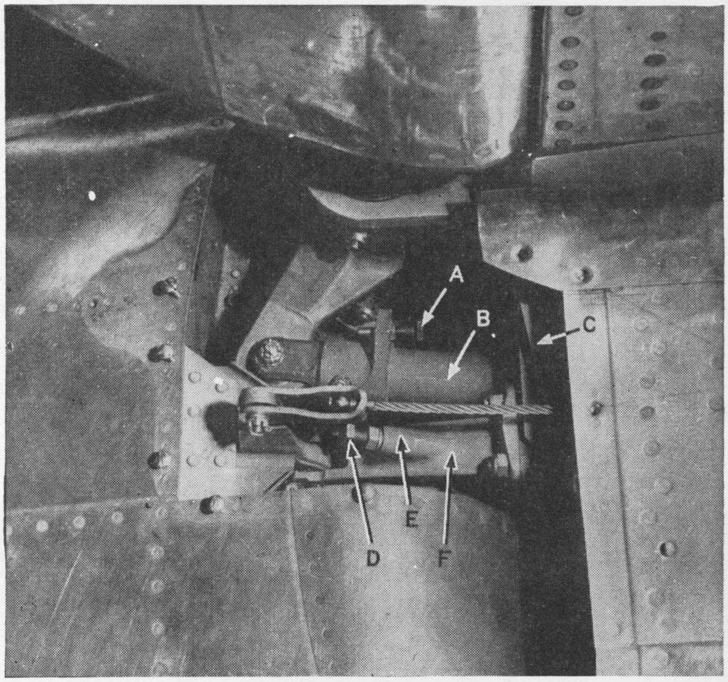


Fig. 1. An adjustable stop nut (*A*) on the P-47N elevator control is set in a fitting attached to torque tube (*B*), the limit being determined by the distance from fitting (*C*). A rudder stop nut (*D*) is set in fitting (*E*) attached to the rudder hinge bracket (*F*).

PART 2. TWIN-ENGINE AIRCRAFT

Grumman Mallard Amphibian

To provide the necessary access to the Mallard's nose compartment forward of the cockpit, instrument panels and controls are grouped toward the port side and a door is provided on the starboard side, in front of the copilot's seat (1). The copilot's rudder pedals swivel 90 deg to make them inoperative and to clear the passage forward.

The center control column has a pilot's branch which may be moved across to the copilot. In addition, a copilot's branch may be readily installed at the center of the Y. This branch, however, may easily be moved out of the way to permit passage to the bow. With this arrangement, a single pilot can perform successful docking and mooring operations without aid.

The overhead engine controls (2) are similar to those of other Grumman designs to facilitate routing of cables aft to the high wing.

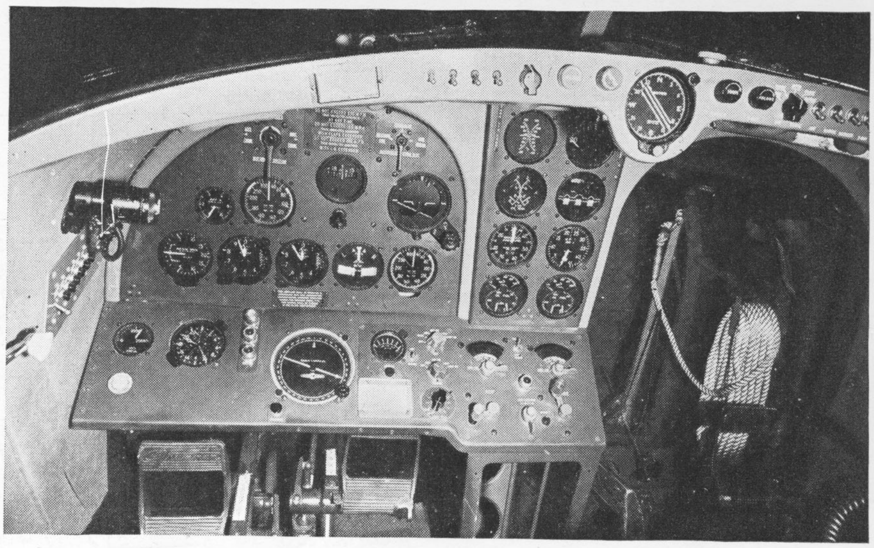


Fig. 1. The Mallard cockpit control arrangement features a bow compartment access door on the starboard side to facilitate mooring and docking.

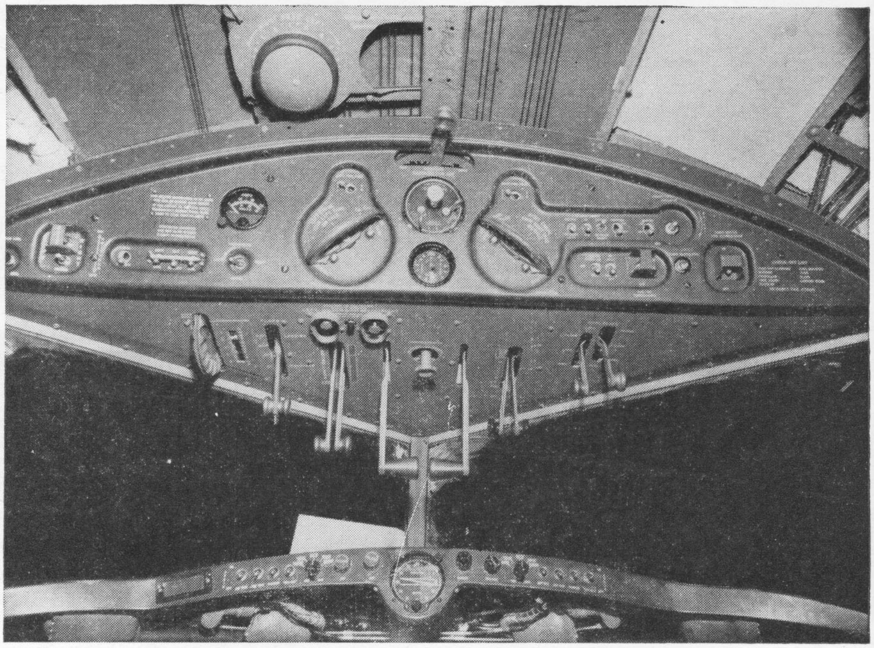


Fig. 2. Overhead engine controls lead directly backward to the high wing.

Messerschmitt Me-262

The main instrument panel (1) of the Me-262 is divided in two sections, with flight instruments on the left (2) and engine instruments on the right (3).

The flight instruments include artificial horizon, combined with bank-and-turn indicator, air-speed indicator (some of which have been red-lined at 658 mph), altimeter, rate-of-climb indicator, repeater compass, and blind approach indicator.

The engine instruments include two tachometers of two-speed variety to give readings from 0 to 3,000 rpm and from 2,000 to 15,000 rpm (generally red-lined at 8,900 rpm); two gas-pressure gauges indicating up to 1 kg per cm^2; two gas-temperature gauges indicating up to 1000°C (with marks on the gauges at 680°); two oil-pressure gauges, and fuel gauges for the front and rear tanks. Called for in the design plans but not installed in the aircraft studied, were two fuel injection-pump pressure gauges, marked at 65 kg per cm^2.

Just below the center of the main panel is the bomb switch panel, marked for dive or level bombing and for instantaneous or delayed action fusing.

Above the main panel is the gun sight, in most cases the old-fashioned REVI 16B reflector type, which can be swung to the right out of the way for take-off and landing.

On a slanting panel just to the left of the main board are valves for emergency operation of flaps and landing gear, oxygen flow indicator, oxygen-pressure gauges (not on all planes), and oxygen valve.

On a horizontal panel just below this unit are position indicators for flaps

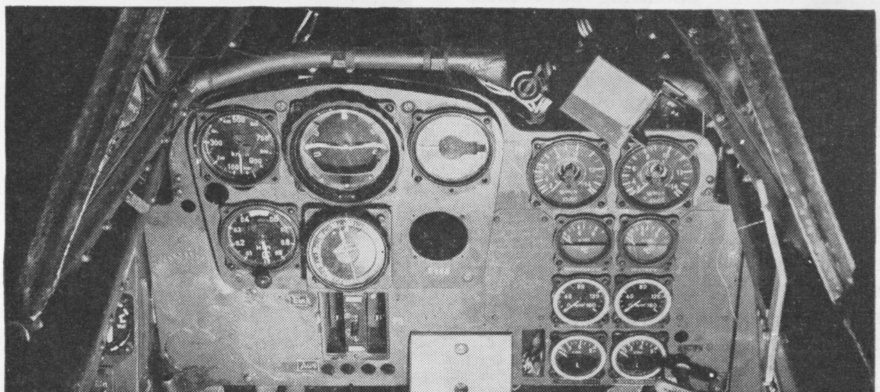


Fig. 1. Main instrument panel, with flight instruments at the left, engine instruments at the right, and bomb switches on the panel at the lower center. Note how the gun sight at the top has been swung to the right out of the way for landing and take-off. Engine instruments from top to bottom are tachometers, gas-temperature gauges, lub oil-pressure gauges, and fuel-supply indicator. The original design called for the installation of gas-pressure indicators alongside temperature gauges, also fuel-injection-pressure gauges alongside oil-pressure gauges.

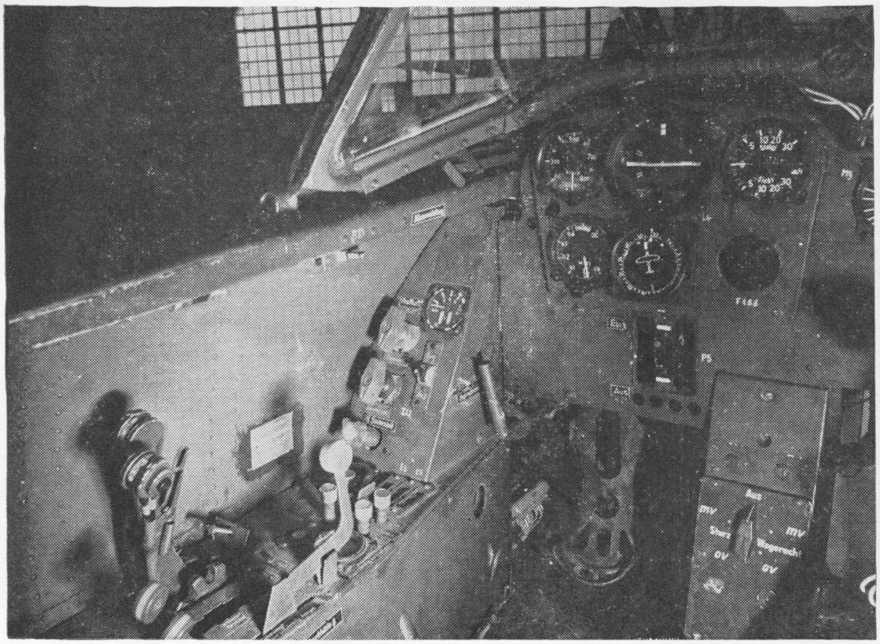


Fig. 2. Left side of the cockpit showing, on the diagonal panel, oxygen-flow indicator, emergency landing gear and flap-operating switches, and oxygen valve. On the horizontal panel, from front to rear, are landing gear and flap position indicators, landing gear and flap-operating buttons, stabilizer pitch indicator and operating switch, emergency master cutoff switch, throttle quadrant, and (not showing) fuel selector valves, rudder trim tab crank, and jet-assisted take-off unit jettison release. At the base of the front panel can be seen a pull handle for the nose wheel brake; at the right, beneath the left windshield panel, is a lever to open or close the cockpit ventilating scoop.

and landing gear, and buttons, immediately aft, for operating both these systems; stabilizer pitch indicator; stabilizer adjusting switch; throttle quadrant; emergency master cutoff switch; fuel selector valves; rudder trim tab crank; and release cable to jettison rocket units for assisted take-off.

On the pilot's right, a corresponding panel contains pitot heater switch; Very signal switches; radio-frequency selector and ON/OFF switches; starter switches for motors; and switches to select the low-speed indicator on the tachometers.

The electric junction box is installed below these panels outside the fuselage cockpit liner, and it is easily accessible from the ground because it is located just above the wheel well.

At the base of the main panel on the left is the pull handle for the nose wheel brake, a unit evidently installed to aid stopping on small turfed fields which the Germans were forced to use in the later stages of the war.

Just under the windshield base frame, also on the left, is a pull lever to operate a small square air scoop set in the fuselage side. This apparently was a late factory modification. The workmanship certainly would never have passed German inspection in the early days.

Unlike the elaborate hinge points provided in the rudder and elevator trim tabs (4), those on the aileron tabs are simply straps bolted to the aileron and hooked around pins on the tab. Like those on the other tabs, however, the trailing edges are neatly flush-riveted.

The flaps are built in two sections: the inboard (which has a 21¾-in. chord) extending 38½ in. from wing root to the power plant, and the outer section extending 48¾ in. from the power plant. With rolled aluminum leading edges, stamped channel section spar, and conventional ribs, they are built in two halves, bolted together except at the T.E. where the skin surfaces are crimped and riveted (with brazier-head rivets) to a ½-in. aluminum strip.

Ball-bearing rollers at both ends of each section run in 7-in. steel guides which are bolted to the auxiliary spar so that, in operation, the flaps move back and down, for the guides slant down 35½ deg from the top to the bottom wing surface. This action is imparted by hydraulically operated

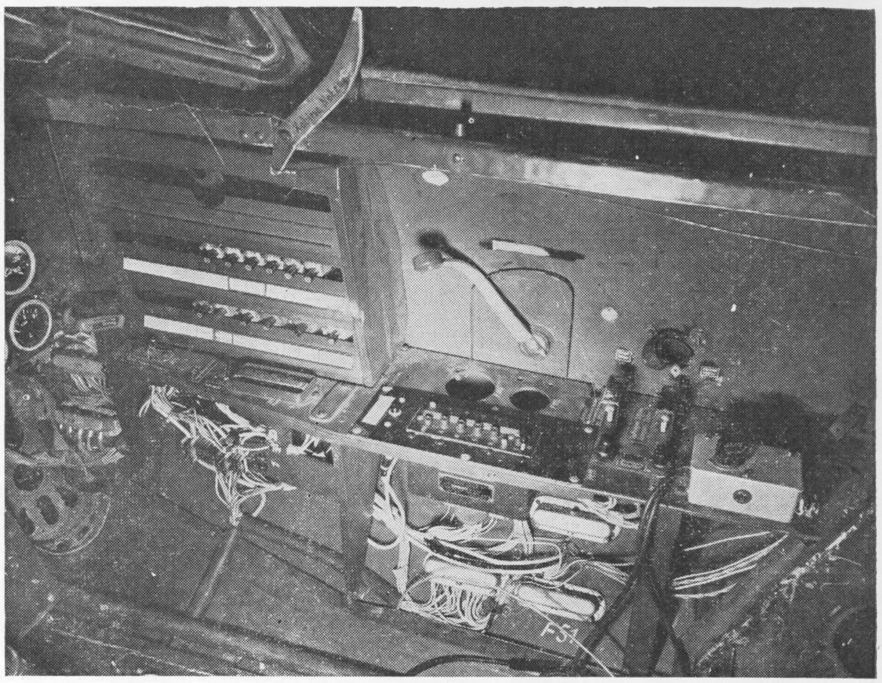


Fig. 3. Right side of the cockpit showing, at the windshield base, canopy jettison lever below which are, from left to right, Pitot heater, Very signal, radio frequency selector and ON/OFF switches, and tachometer low-speed selector switches. The curved handle in the fuselage side is a bomb release. Pulling it clear back beyond the bomb-release stop jettisons bomb racks.

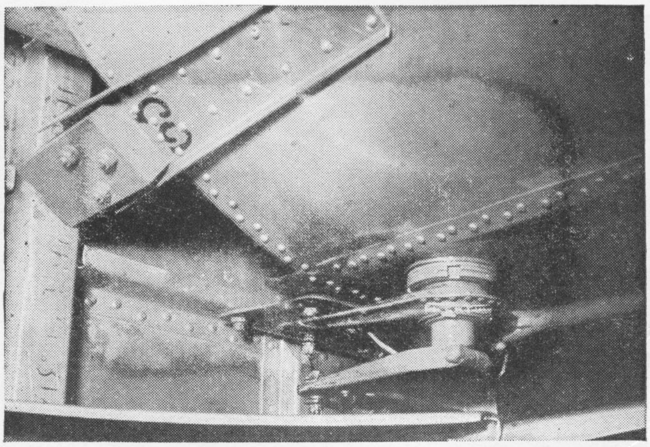


Fig. 4. Elevator bell crank and trim tab (unused because the trim tabs were riveted to the elevators) over the auxiliary spar attached to the bottom of the cylindrical cockpit liner.

toggles which force the flap bodily aft approximately 5½ in.—and down because of the guide—except for the final 5 deg of flap action, which is a pivot movement. The upper wing surface extends out over the flap, so that, even when extended to the full 50 deg, the flap L.E. is shrouded for 1½ in.

The flap-actuating cylinder is set at a 45-deg angle to the front face of the main spar directly ahead of the oleo hinge point and is attached to one corner of a triangle whose apex is its hinge point on the spar. Where the piston attaches, there is also attached a push-pull rod which extends across the plane to the left to a bell crank set just over the left power plant, with a push-pull rod going straight back to the aft face of the auxiliary spar. Here it is connected to an arm extending down from

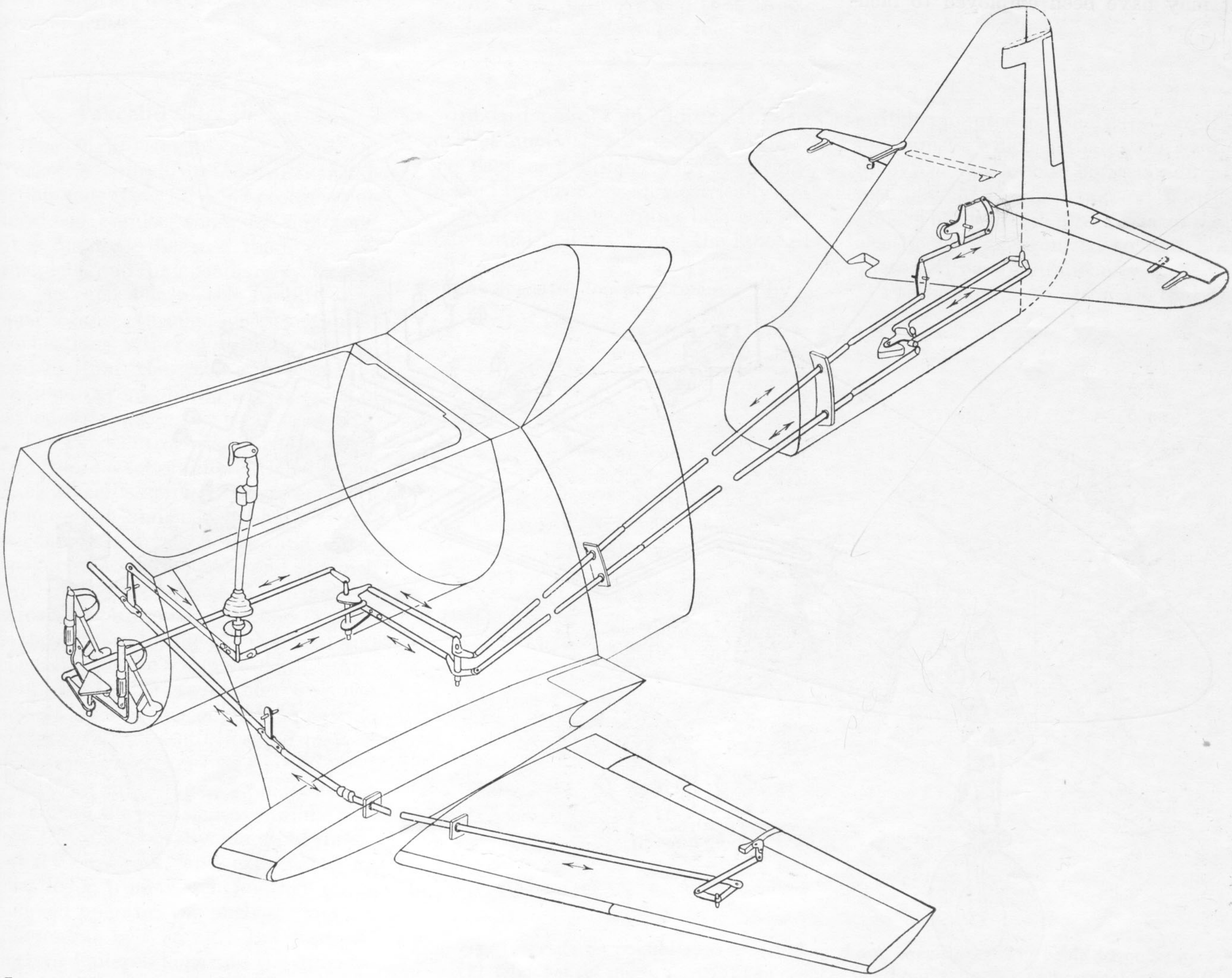


Fig. 5. Phantom view of the Me-262 surface control system. Note the adjustable mass balance in the linkage of both elevators and rudder. These are in addition to balances built into the control surface themselves.

a torque tube connected to the toggles which force the flaps back and down.

The right side flaps are actuated by a tube going straight back from the base of the triangular member connected to the actuating piston.

Pilot error in forgetting to lower the landing gear is avoided by the system's being so arranged that the flaps cannot be extended until the landing gear is down.

The left outboard flap on the aircraft examined has markings at 0, 10, 20, 30, 40, and 50 deg, with the 20-deg mark in red for take-off.

Three of the lower wing skin panels, extending over three ribs each, are held in place by flush screws placed about 1½ in. apart. While the primary purpose may have been to facilitate access, the small number of units requiring maintenance gives rise to the belief that it may have been employed to facil-

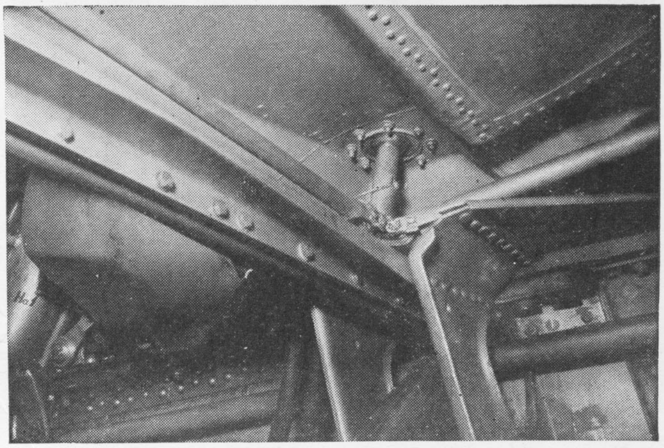


Fig. 6. Bottom of the control stick, seen extending through a ball-and-socket joint in the bottom of the cockpit liner, with an aileron torque tube extending to the right and an elevator tube extending aft.

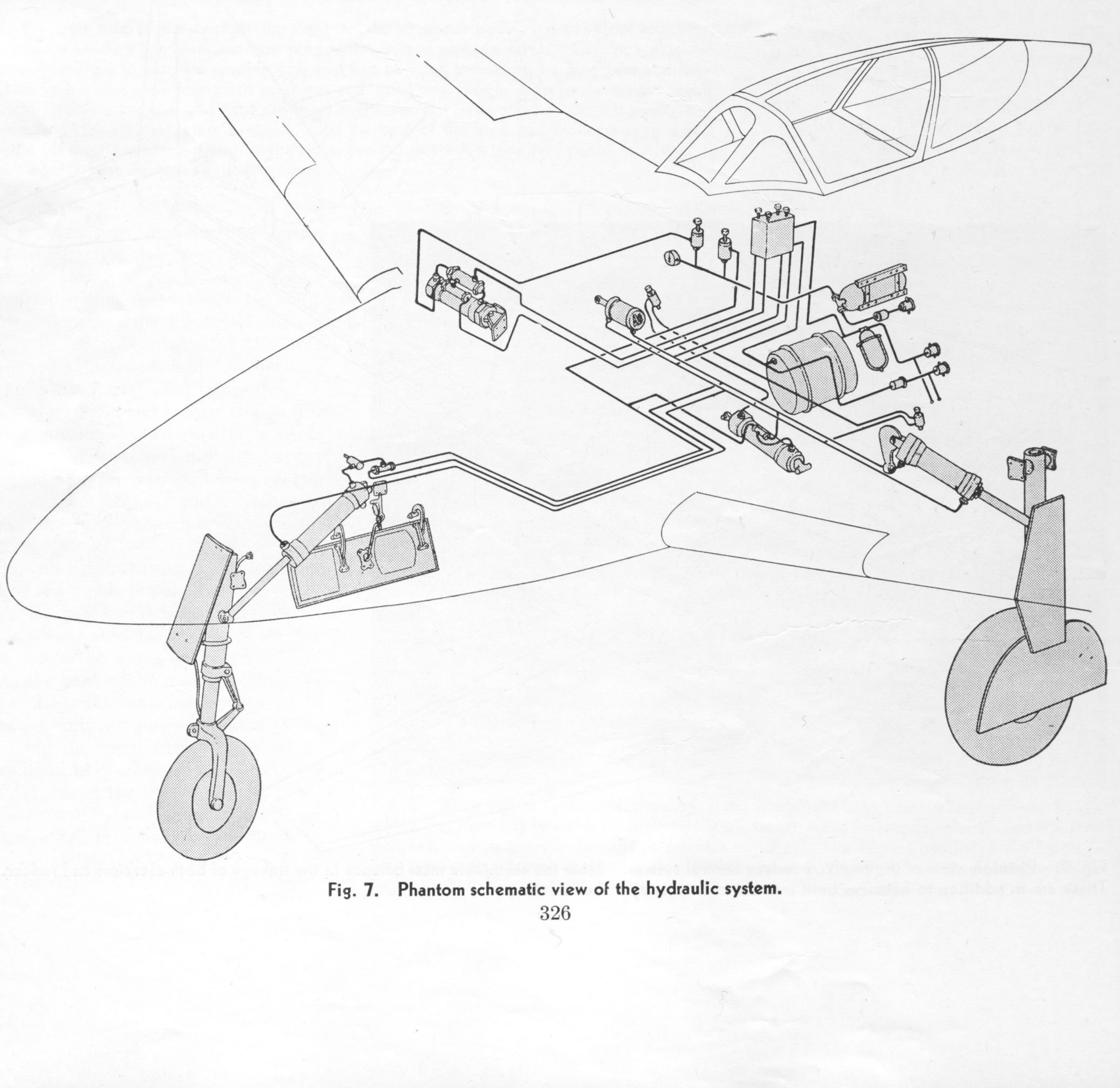


Fig. 7. Phantom schematic view of the hydraulic system.

itate production by eliminating blind riveting.

Both landing gear and flap-operating systems have connections with a compressed-air bottle which can be cut in for emergency operation of the two systems.

The surface controls (5) present several odd and interesting features. The control stick, for example, is mounted in a ball-and-socket joint set in the bottom of the cockpit liner (6), extending down 4 in. and ending in a welded angle bracket. Attached by a ball-bearing joint to one face of this bracket is a $\frac{3}{4}$-in. tube extending to the right above the main spar. Just inside the fuselage and bolted to the top boom of the spar, is a bell crank from which 1-in. push-pull tubes extend, with one universal joint in each at the fuselage side (to compensate for spar sweepback) out to bell cranks set just ahead of the aileron control arms.

Attached to the aft face of the angle bracket on the stick is a $\frac{5}{8}$-in. elevator-operating tube aft to a self-aligning ball-bearing bell crank set just over and ahead of the auxiliary spar, from which a 1-in. tube extends to the left side of the fuselage and another bell crank to connect to a similar-sized push-pull tube going aft. A third bell crank is set in the empennage near the stabilizer L.E. Extending straight aft from this crank is another push-pull rod connected to the elevator horn and, just ahead of the horn, a large mass balance which can be ground-adjusted on the fulcrum.

This balance is in addition to those already noted as being set in the elevators themselves and may be a late modification. Reports from abroad indicated that at speeds over 500 mph, the ailerons and elevators became extremely hard to move and that an extendable control stick designed to give increased leverage had been developed. However, no such stick, or provisions for its installation, could be found in the plane studied, and it is possible that the mass balance just discussed was utilized in its place.

Rudder pedals are very similar to those on the FW-190, incorporating the main wheel brake pedals as integral units. A torque tube extends aft from the right pedal inside the cockpit liner, then through a seal to a bell crank where another tube extends to the left side of the fuselage to a second crank which is connected with the push-pull tube extending to the empennage, where a third crank, with adjustable mass weight, is connected to double tubes connected to the enclosed rudder horn.

A schematic view of the Me-262 hydraulic system is shown in (7).

Fairchild C-82 Packet

The flight control system of the Packet is a duplicate and dual installation consisting of cable sectors, pulleys, bell cranks, and push-pull rods. It is duplicate because there are two complete and independent systems—one on each side of the aircraft—and dual because, through a series of interconnections, either system may be operated from the pilot's or copilot's station in event of failure of any part of either system.

The two control wheels in the cockpit operate a set of differential ailerons. Each wheel is splined to one end of a torque shaft, and the two shafts are interconnected by a chain and cable hookup. A chain, at the end of which two cables are attached, engages a sprocket mounted in bearings housed in the forward torque tube support and connected to the torque tube by a universal joint. The two cables run down and aft over a series of guide pulleys to a triple-grooved sector located just aft of the center section rear spar.

Another cable engages this sector, is led behind the rear spar over guide pulleys to a horizontally mounted differential bell crank, and extends to an idler lever from which another push-pull rod operates the outboard aileron differential bell crank. Between the outboard aileron horn and the differential bell crank, the aileron-operating rod is installed.

Inboard ailerons, in addition to their normal functions, are used also to assist the flaps in landing. This is accomplished by inserting an electrically operated screw actuator unit between the differential bell crank and the inboard aileron horn.

The actuator motor is operated by a switch mounted on the flap-operating mechanism which actuates the switch upon reaching a point corresponding to just beyond the flap take-off position (1). The two aileron actuators are electrically synchronized so that both ailerons drop simultaneously.

The linkage is so arranged that the

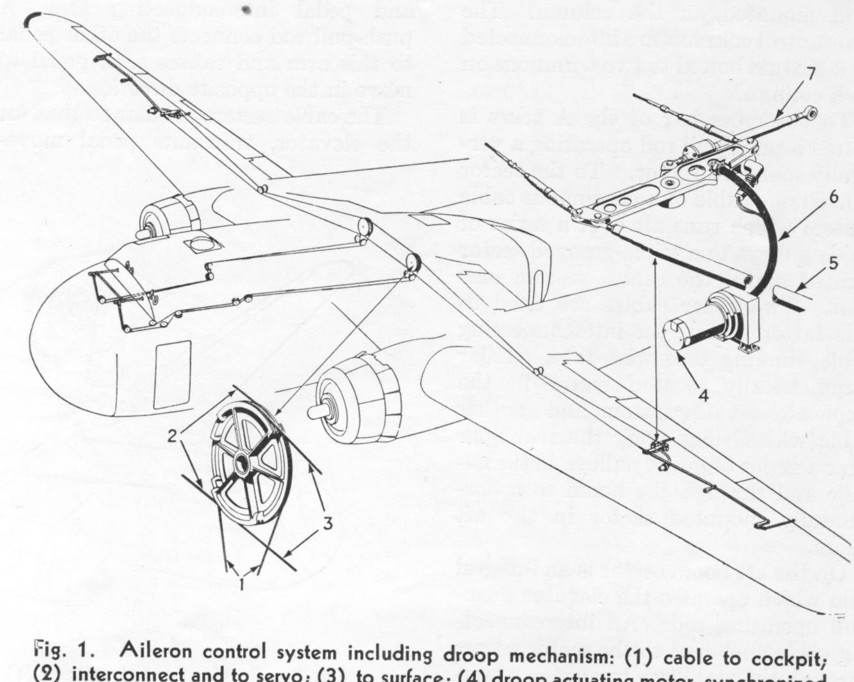


Fig. 1. Aileron control system including droop mechanism: (1) cable to cockpit; (2) interconnect and to servo; (3) to surface; (4) droop actuating motor, synchronized with the flap for landing; (5) push-pull connection between the inboard and the outboard aileron; (6) flexible shaft; (7) screw-jack actuator.

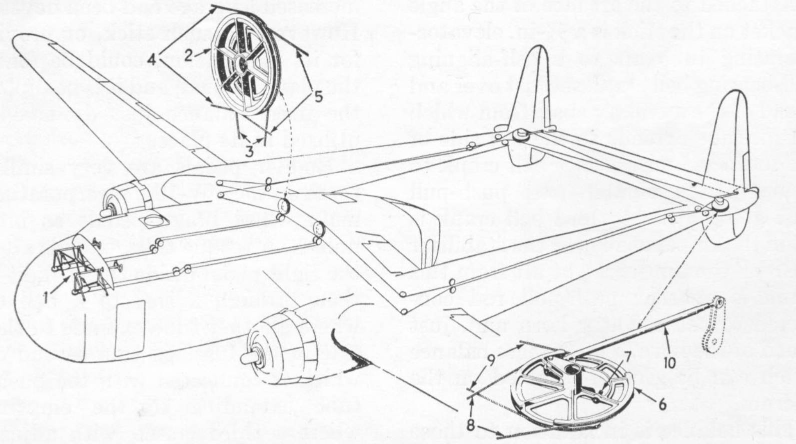


Fig. 2. Elevator control system; (1) interconnect truss; (2) sector wheel at rear spar; (3) cable to cockpit; (4) to surface; (5) interconnect and to servo; (6) sector for surface movement and interconnect; (7) stop; (8) to rear spar sector; (9) interconnect; (10) push-pull rod to surface horn.

control wheel moves 150 deg either side of neutral to move the aileron from 12 deg down to 24 deg up.

Elevator control (2) is obtained by fore-and-aft movement of the control column, pivotally mounted on an inverted V truss in the front end and an A truss in the rear. The column is fastened to the forward truss through the housing which holds the aileron sprocket, and to the rear truss by a gimbal engaging a ball-bearing trunnion mounted on the column. The two control columns are interconnected by a K truss bolted to two trunnions on each column.

To the cross bar of the A truss is bolted a push-pull rod operating a vertically mounted sector. To the sector is fixed one cable of a continuous cable system which runs aft over a series of guide pulleys to a triple-grooved sector located aft of the center section rear spar. Two other cables are fixed to this latter sector: an interconnecting cable running crosswise to a similar symmetrically located sector in the duplicate elevator system, and another cable which runs along the rear spar over a series of guide pulleys to the nacelle and through the boom to a horizontally mounted sector in the aft boom.

On the aft boom sector is an integral arm which operates the elevator push-pull operating rod. An interconnecting cable anchored to the sector passes through the stabilizer to engage a similar sector of the duplicate system installed in the opposite aft boom.

The control column moves a total of 18 in. to move the elevator 25 deg down to 35 deg up.

The rudders (3) are controlled by the movement of a pair of top-hung-type pedals adjusted for long- and short-leg positions by a pawl connecting the pedal to a ratchet on the actuating arm. Through a push-pull rod, the actuating arm imparts movement to an arm bolted to a horizontally mounted torque shaft carrying the rudder sectors and pedal interconnecting arm. A push-pull rod connects the other pedal to this arm and causes each pedal to move in the opposite direction.

The cable system, similar to that for the elevator, transmits pedal movement to an interconnecting sector at the rear spar and then to the sector at the aft boom where the two systems are again interconnected. From the latter sector, cables pick up a set of rudder horns mounted on a torque tube by which both the upper and the lower rudders are actuated.

With pedal movement of 22 deg, rudders correspondingly move 35 deg right or left.

Surface locks are located close to the control surfaces to protect against damage by ground dust. Each lock is, basically, a rotating cam which mates in the locked position with a machined surface on the bell crank or sectors. Lock cams are actuated by cables attached to interconnecting sector wheels, and pulling a handle located to the pilot's left actuates all lock cams simultaneously.

In the locked position, the operating handle lies across the pilot's seat and prevents him from taking off with surfaces locked. In the event of cable failure in flight, the lock control is designed to keep the cams in unlocked position (4).

To avoid subjecting control systems to overload by pilot or by gusts on the surfaces, two sets of surface control stops are installed: one in the cockpit at the steel structural mount, and the other at the operating bell cranks closest to the surface, with the provision for adjustment to assure the proper travel of the movable surfaces.

Trim tabs are used on the inboard aileron and rudders, and a spring tab and trim tab on the elevator. The trim tab controls (5) are conventional

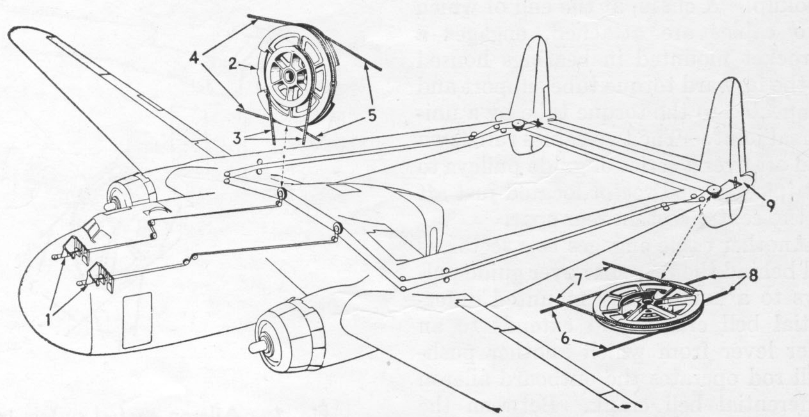


Fig. 3. Rudder control system: (1) actuating sectors in the cockpit; (2) sector on rear spar; (3) cable to cockpit; (4) to surface; (5) interconnect; (6) to rear spar sector; (7) interconnect; (8) to horn; (9) location of stop.

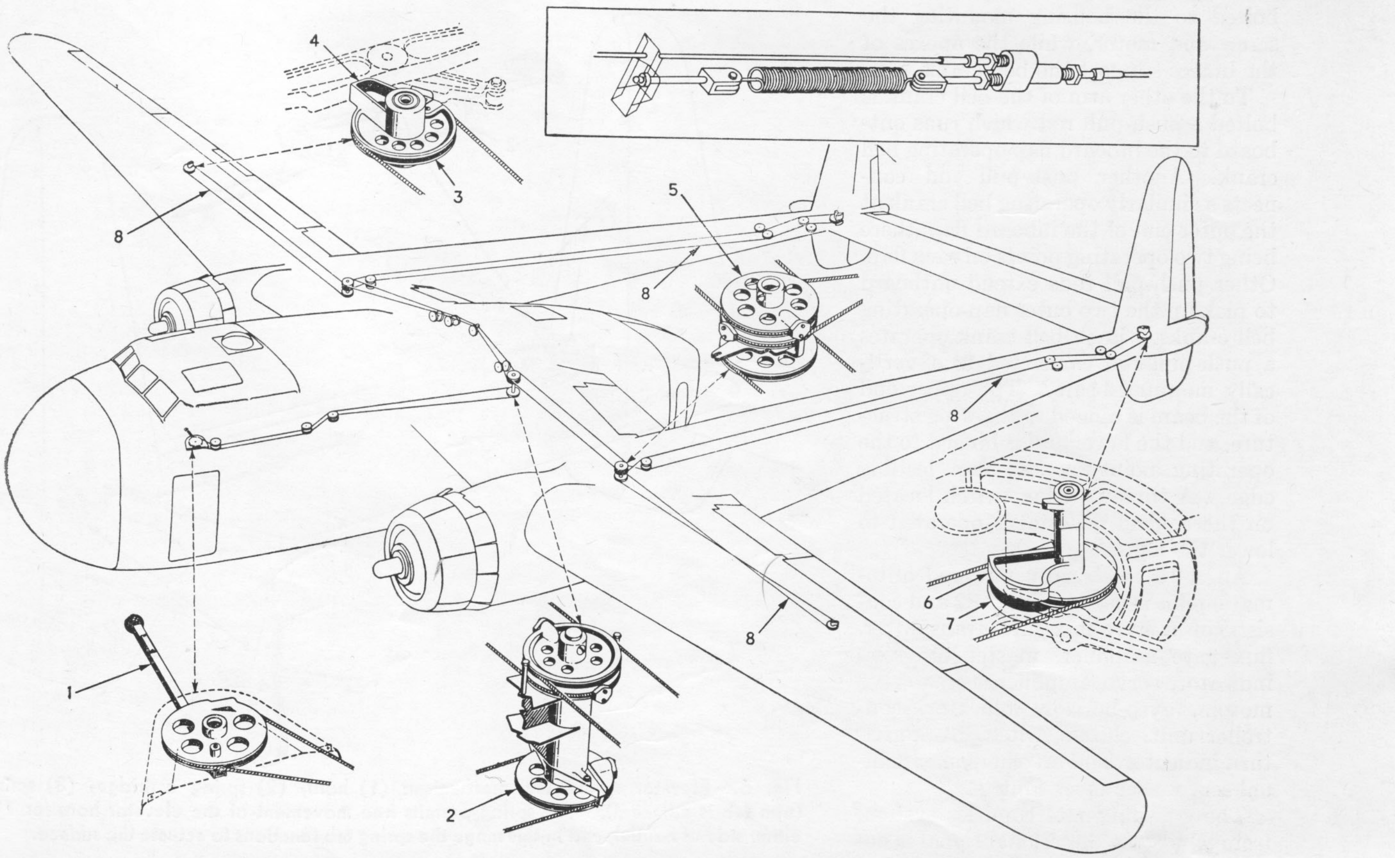


Fig. 4. **Surface control lock system: (1) locking arm extending across the pilot's seat (locked position); (2) tie-in sector to locking arm; (3) aileron cam lock; (4) cam edge; (5) intermediate sectors; (6) elevator cam edge; (7) rudder cam edge. The inset shows an emergency release for the cam to hold it in open position if the control cable is shot away or breaks in flight. Unit locations are seen at (8) in the main sketch.**

in design and consist of control units mounted accessible to pilots, cable drums, pulleys, cable, and irreversible screw jacks at the tabs. Tab control units incorporate dials and stops and allow for a small amount of overtravel.

The elevator tab to the left of the center line is a trim tab, and the one on the right is a spring tab. Spring tab (6) action is accomplished by holding the elevator horn in neutral, balanced against a 142-lb compression spring (mounted within the elevator) to permit 7½ deg of horn motion either side of neutral in relation to the elevator. Horn motion is transferred by push-pull rods and levers to produce 30 deg up or down movement of the tab in the direction desired to aid the movement of the elevator.

A rigid push-pull rod and bell-crank system operates the four flaps (7). A motor-operated screw jack and nut actuator is located in the fuselage center rear upper section. Rotation of the screw causes the double-lugged nut to move fore and aft on the screw, and to each lug is bolted a horizontally mounted bell crank pivoted between two V braces, one on top and one on bottom.

The free ends of the V braces are

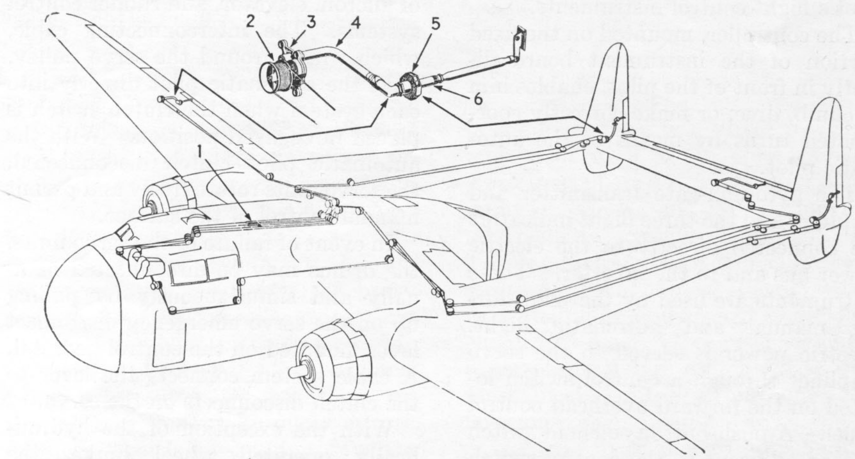


Fig. 5. Tab control system: (1) tandem cable connections in the rudder system; (2) grooved cable drum; (3) gearbox; (4) flexible shaft; (5) tab screw-jack mechanism and mount; (6) irreversible screw jack.

bolted to the housing mounting the screw and motor, while the apexes of the braces support the bell crank.

To the other arm of the bell crank is bolted a push-pull rod which runs outboard to the inboard flap operating bell crank. Another push-pull rod connects a similarly operating bell crank at the outer end of the inboard flap, there being two operating points on each flap. Other push-pull rods extend outboard to pick up the two outer flap-operating bell cranks. Each bell crank operates a push-pull rod connected to a vertically mounted beam. The upper end of the beam is hinged to the wing structure, and the lower end is hinged to the operating point on the flap leading edge. A three-position switch located on the control pedestal is operated to lower the flaps.

An A-10 electrically powered automatic pilot is used in the C-82 and consists of a gyro-flux-gate transmitter, flux gate amplifier, master direction indicator, servo amplifier, three servo motors, gyro-horizon indicator, controller unit, clutch switch, bank-and-turn indicator, and an emergency manual servo disconnect control.

The gyro-flux-gate compass system, from which the directional signal is derived, includes a transmitter, amplifier, master direction indicator, and two repeater indicators. The flux-gate transmitter is located on the tip of the left wing outer panel, and the amplifier on the left side vertical bulkhead in the front section of the fuselage. The master direction indicator is mounted on the instrument board in front of the pilot and, with the bank-and-turn and gyro-horizon control, forms part of the pilot's flight control instruments.

The controller, mounted on the fixed portion of the instrument board directly in front of the pilot, enables him to climb, dive, or make correctly coordinated turns by means of the automatic pilot.

The gyro-flux-gate transmitter and amplifier and the three flight indicators are connected directly to the electric power bus and to the inverter. These instruments are used by the pilot during manual and automatic flight. Electric power is served to the servo amplifier through a control switch located on the forward overhead control panel. A push-button solenoid switch located adjacent to the control switch engages or disengages the servo motors. The servo motors may also be disengaged electrically by push-button switches, one located on each control wheel.

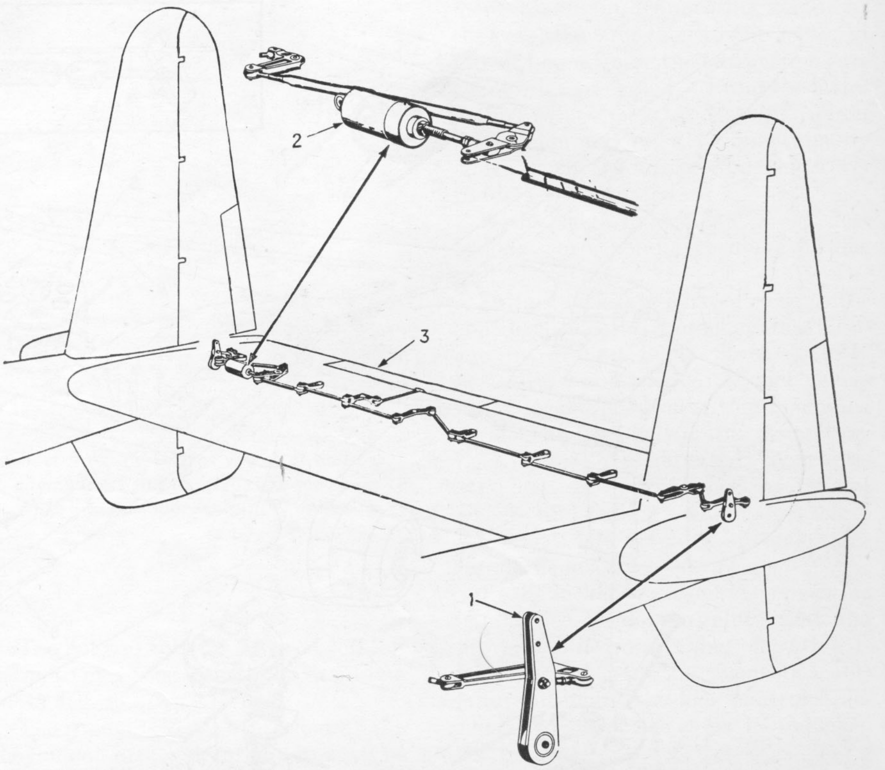


Fig. 6. Elevator spring tab mechanism: (1) horn; (2) spring cartridge; (3) spring tab (trim tab is adjacent). The spring permits free movement of the elevator horn for 7½ deg either side of neutral, and in this range the spring tab functions to actuate the surface.

The servos are rigidly mounted aft of the center section rear spar. They are staggered in the fore-and-aft direction to place the three servo pulleys in line with the interconnecting cables of aileron, elevator, and rudder control systems. The interconnecting cable, which wraps around the servo pulley, links the automatic pilot directly into each system when the clutch switch is placed in engaged position. With the automatic pilot clutch disconnected, the servo units rotate freely and permit manual control of the surface.

In event of failure of the servo units, the drums may be disconnected manually and simultaneously by pulling up on the servo emergency disconnect lever mounted on the control pedestal. A cable system connects the lever to the clutch disconnects on the servo.

With the exception of the hydraulically operated wheel brake, the Packet uses electric power. A 24-volt d-c single-wire bus system, supplied by a 34-amp-hr battery, 200-amp high-speed generator driven by each engine, and a 200-amp auxiliary power plant, furnishes power to 52 separate circuits, which make up the wiring system. All wiring, with the exception of the ignition system, is of the open type and is supported by quick-opening cushioned clamps. Wires are protected, where necessary, by Vinylite insulating tubing.

The bus system extends from the main junction box (located in the cargo compartment) from which three branches lead—one to each junction box in each nacelle, and a third to a nose junction box.

Two inverters are used to supply 440-cycle alternating current to operate the automatic pilot and radio equipment.

Radio equipment consists of 10 receivers and 6 transmitters, to which are led 14 externally mounted antennas. The twin booms and large fuselage permit the use of long antennas, widely separated from the structure for the command and liaison sets.

Two command sets are used, one of

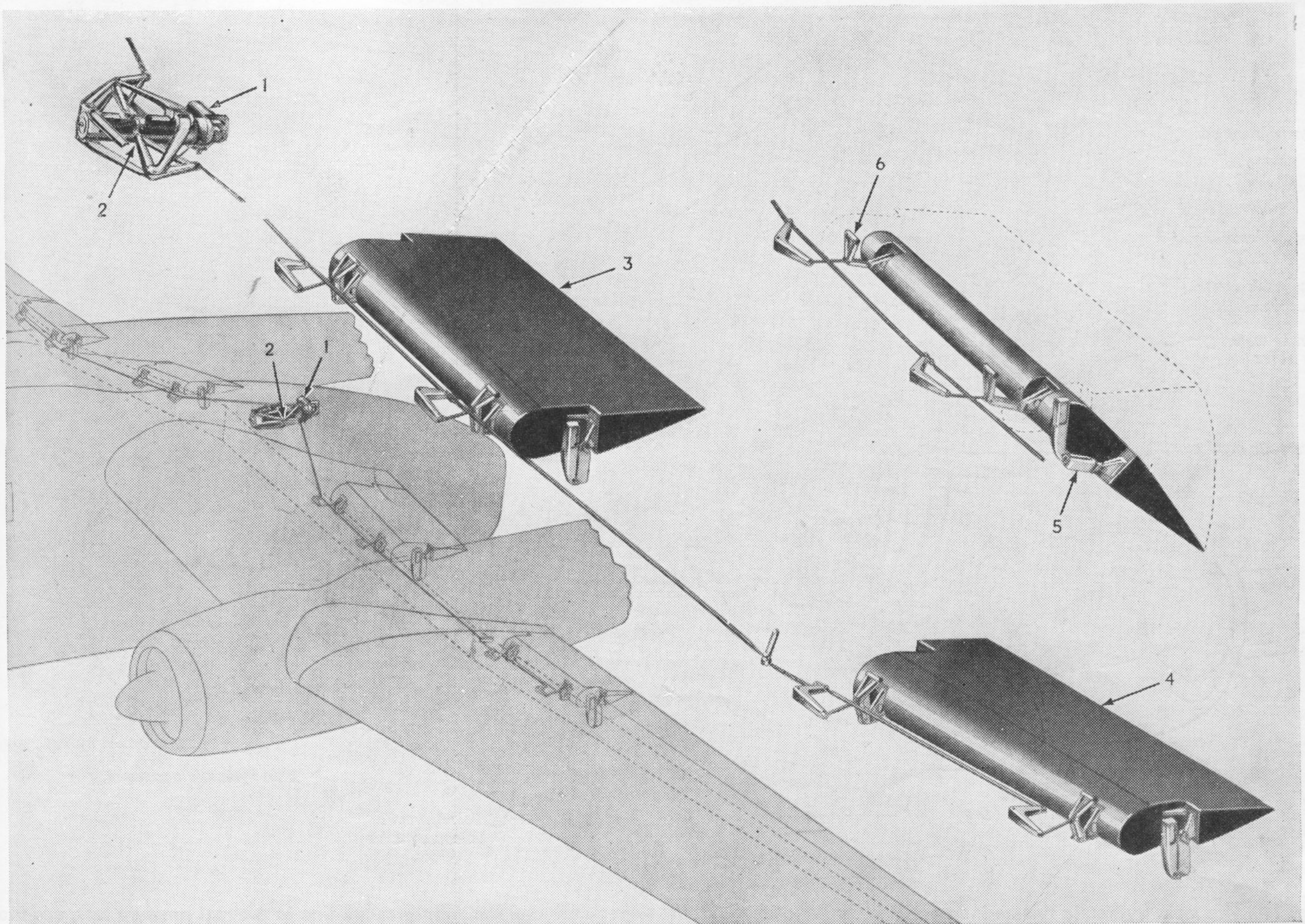


Fig. 7. Flap-operating mechanism: (1) motor; (2) screw and nut actuator; (3) inboard flap; (4) outboard flap; (5) hinge link; (6) actuating lever

high and one of very high frequency, for short-range plane-to-plane and plane-to-base communication. A liaison set is used for long-distance plane-to-base operations. Two radio compasses permit simultaneous bearings to be taken from two ground stations, while two radar sets, one of short and one of long range, are used for navigational purposes.

An absolute altimeter indicates the altitude of the plane above the terrain. To facilitate landing in bad weather or at night, blind landing equipment also is provided.

An identification set and six interphone stations complete the radio system.

Curtiss C-46 Commando

The main hydraulic system (1) of the C-46 is of the accumulator type, comprising two engine-driven pumps, a check valve in the main pressure line to prevent loss of pressure, and two accumulators, one in the accessory compartment under the floor, and a reserve for emergency brake operation located above the floor in the cockpit.

Check valves also are installed in the main pressure line from the engine pumps to provide normal operation of the system in the event of failure of one engine or pump. A fluid reservoir is located above the floor at the forward left-hand corner of the main cargo compartment, and an emergency hand pump is set between the pilots just behind the control pedestal.

All hydraulic system fittings are aluminum alloy except on the brake lines and special nacelle swivel and tubing assemblies, where they are stainless steel for structural purposes. Normal pressures are 1,200 psi for landing gear, brakes, surface controls, flaps, and cowl flaps and, through a bleeder valve, 150 to 200 for the automatic pilot.

The Curtiss-designed flaps operate, in the first stage, in a direct rearward movement of 3 in. to create a slot. Next they pivot downward to a maximum of 35 deg for landing or any intermediate position for take-off (2). The flap hydraulic system includes two struts for each flap; a control valve; two dual flow equalizers; single flow equalizer; relief valve and essential lines; check valves and fittings, with mechanical control from one flap lever on control quadrant (3).

Designs to make cargo handling easier involve even the hydraulic system, for it supplies power for a loading winch set in the main cargo

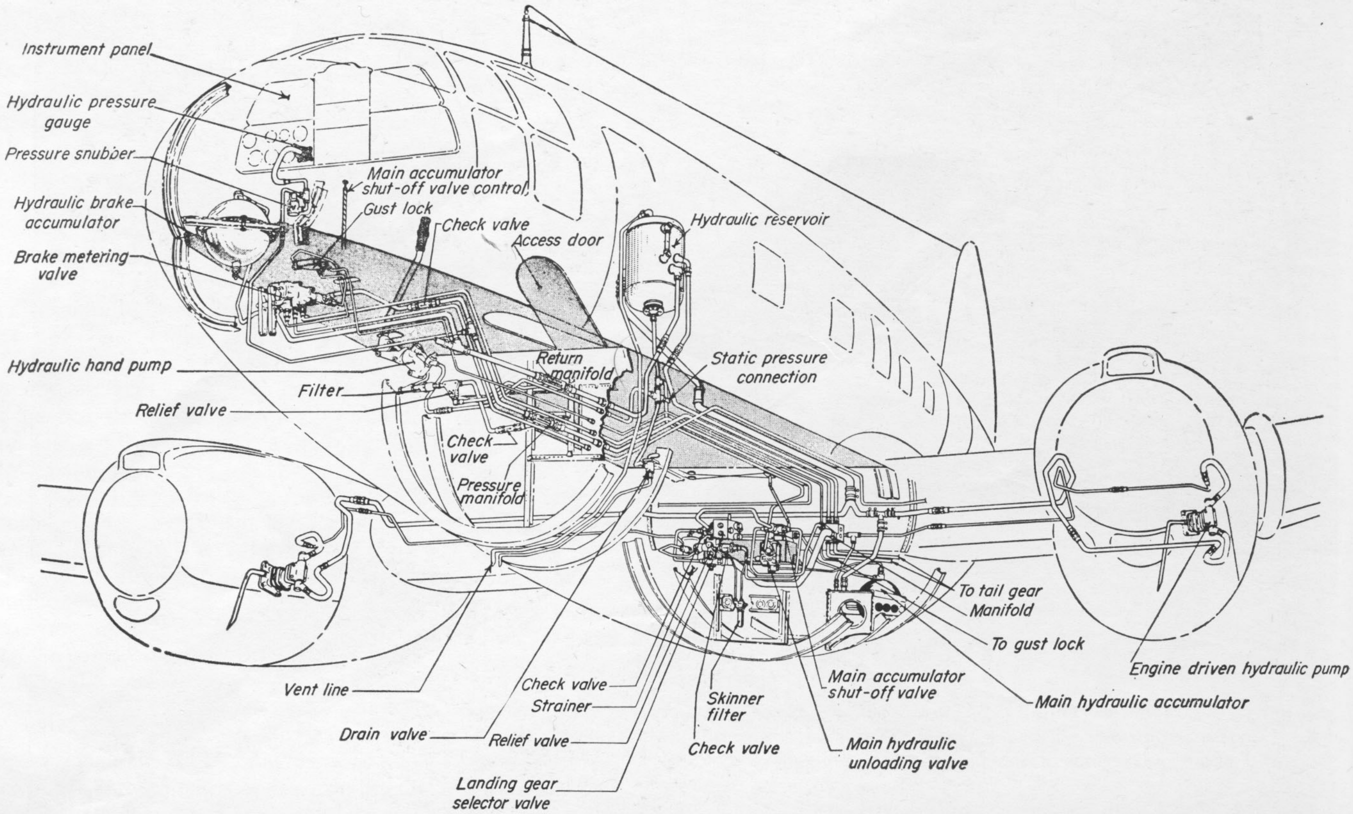


Fig. 1. The main hydraulic system includes two engine-driven pumps, a check valve in the main pressure line to prevent pressure loss, and two accumulators, one of which is located under the floor in the accessory compartment with reserve for the brake system located above the floor in the pilot's cabin, ahead of the instrument panel. Normal pressure is 1,200 psi for landing gear, brakes, surface controls, flaps, and cowl flaps, with the automatic pilot operating at 150 to 200 through a bleeder valve.

compartment floor just behind the bulkhead aft of the cockpit.

When the Commando's prototype went into design, it was sought to keep pilot fatigue to a minimum through the use of a hydraulic boost system for all controls. This system, while an integral part of the control setup, was designed to supplement rather than supplant, for all controls were direct-connected and so designed that failure of any one mechanical unit in elevator, rudder, or ailerons would not result in loss of action of any other part of the system.

The hydraulic boost setup, then, was designed to "cut in" on the system, the boost cylinders being located at the control horns of the various surfaces. It was developed ultimately to have a constant 3:1 ratio so that the pilot's "feel" of the controls was retained.

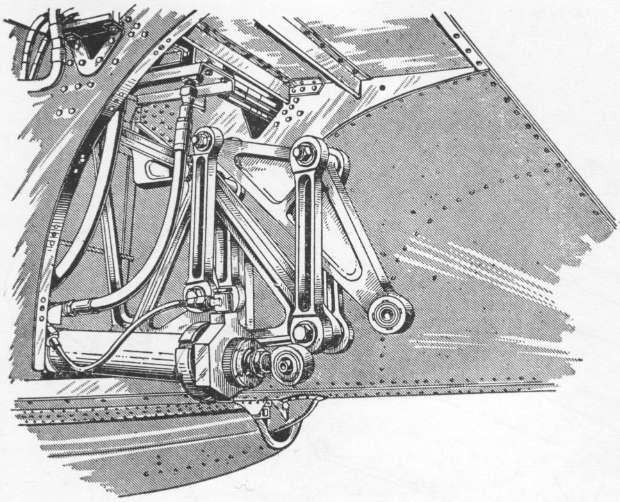
In the aileron control system (4), control cables run under floor beams to a hinge attached to the rear spar in the aft lower cargo compartment. The hydraulic boost control "cuts in" at this point.

Since, however, the Commando has proved itself a stable, easy-to-fly craft, the theoretical considerations calling for the control boost have been found to be partly unnecessary. Also, the wartime operation of constantly growing numbers of planes in every war theater embracing all conceivable weather conditions meant that maintenance was far different from peacetime airline operations from well-established bases. These conditions, coupled with the fact that skills of vastly increased numbers of hurriedly trained men simply could not equal the high levels of airline operation, called for elimination of every possible maintenance-requiring unit. Thus, the hydraulic control boost system for the rudder was eliminated, with this control now being straight manually operated.

The readily removable tip of the fuselage nose (5) facilitates inspection and service of wiring and plumbing back of the instrument panel.

The electric system follows conventional practice and design, consisting of two 24-volt batteries, two inverters for 400-cycle alternating current. Components using electricity include: power plants, radio, warning units, autosyn, instruments, and heater units.

Standard instrument equipment in the C-46 is as follows: altimeters (two); turn indicator; flight indicator; two airspeed indicators; turn-and-bank indicator; climb indicator; radio and magnetic compasses; manifold-pressure



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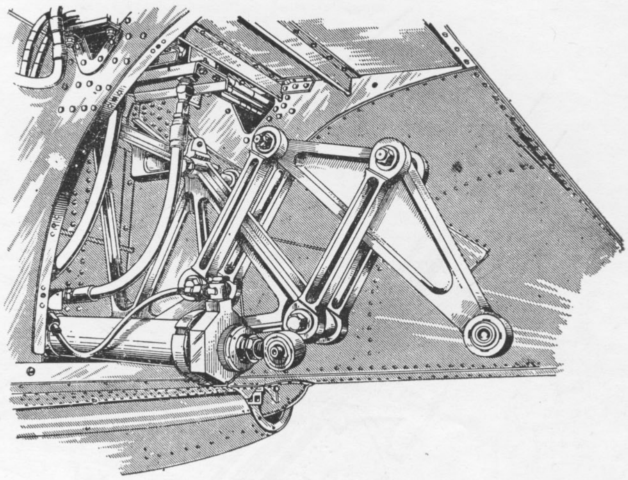

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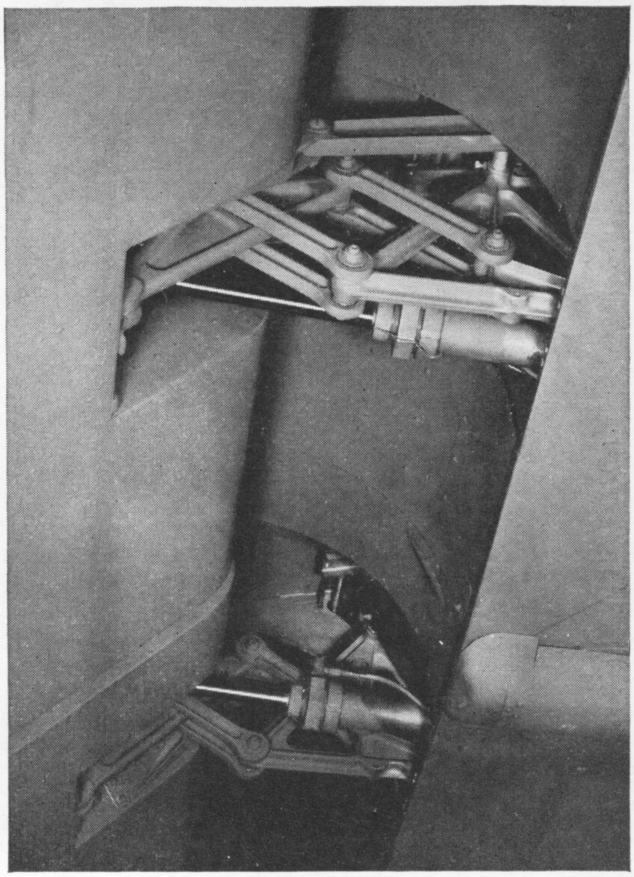


(*c*)

Fig. 2. The first stage of operation of Curtiss-designed hydraulic flaps is a direct rearward movement of 3 in. to create a slot. Then, via the pantograph action mechanism shown here, flaps pivot downward to maximum of 35 deg for landing, or any intermediate position for take-off. The sketch (*a*) shows flap-actuating mechanism in retracted or UP position; (*b*) in extended or DOWN position. Photograph (*c*) gives the detail of the outboard flap mechanism (top) and inboard mechanism with the flaps in DOWN position.

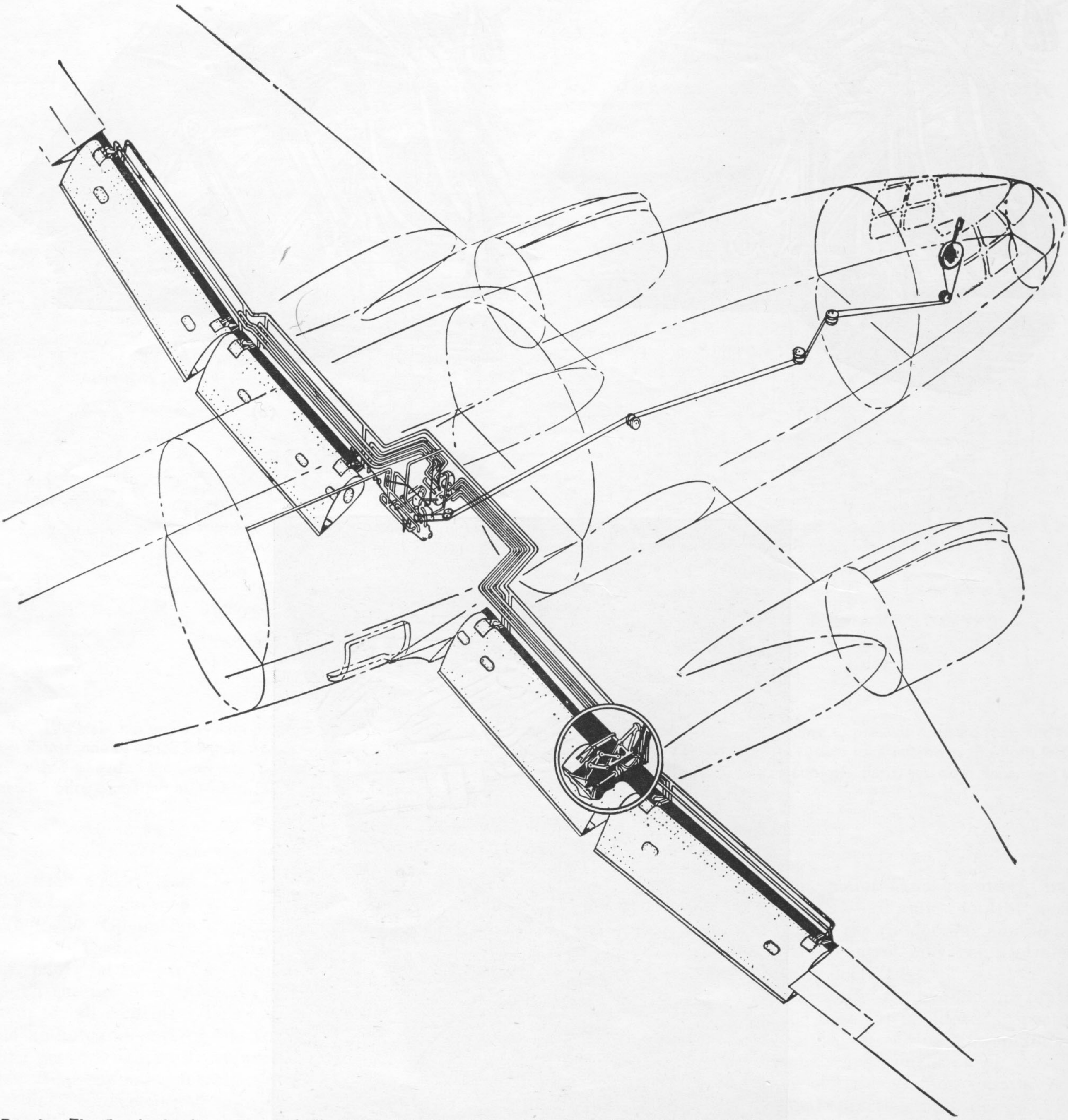


Fig. 3. The flap hydraulic system includes eight struts (two for each flap), control valve, single flow equalizer, two dual flow equalizers, relief valve and essential lines, and check valves and fittings, with mechanical control from one flap lever on the control quadrant.

gauge; tachometer; carburetor-temperature gauge; free-air-temperature gauge; oil-temperature gauge; oil- and fuel-pressure gauges; three fuel-level gauges; fuel flowmeter gauge; cylinder head temperature gauge; mixture indicator; main hydraulic pressure gauge; automatic pilot pressure gauge; flap-position indicator; vacuum gauge; deicer-pressure gauge; clock; two accelerometers; oil-level gauge; astro compass; four oxygen-flow indicators; two voltmeters; drift meter; four oxygen-pressure gauges; two ammeters; and a remote indicating compass.

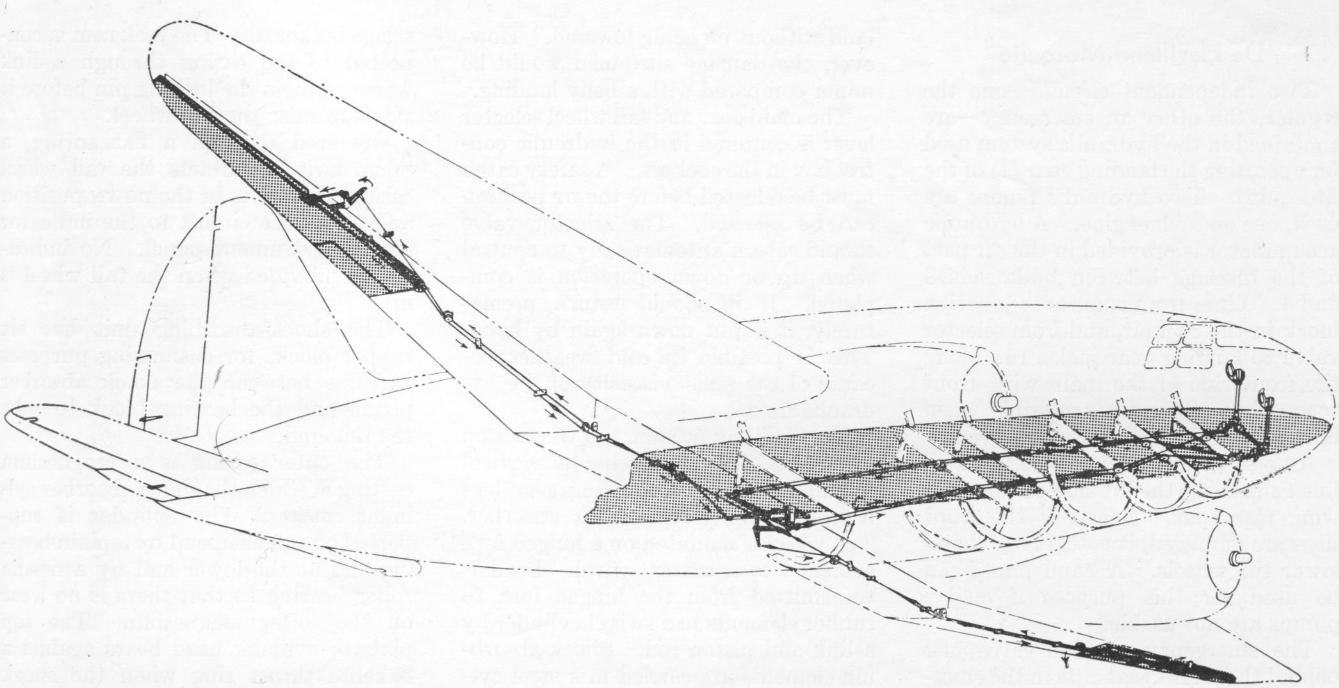


Fig. 4. Phantom view of the aileron control system. Control cables run beneath floor beams to a hinge attached to the rear spar in the aft lower cargo compartment. The hydraulic boost control "cuts in" at this point.

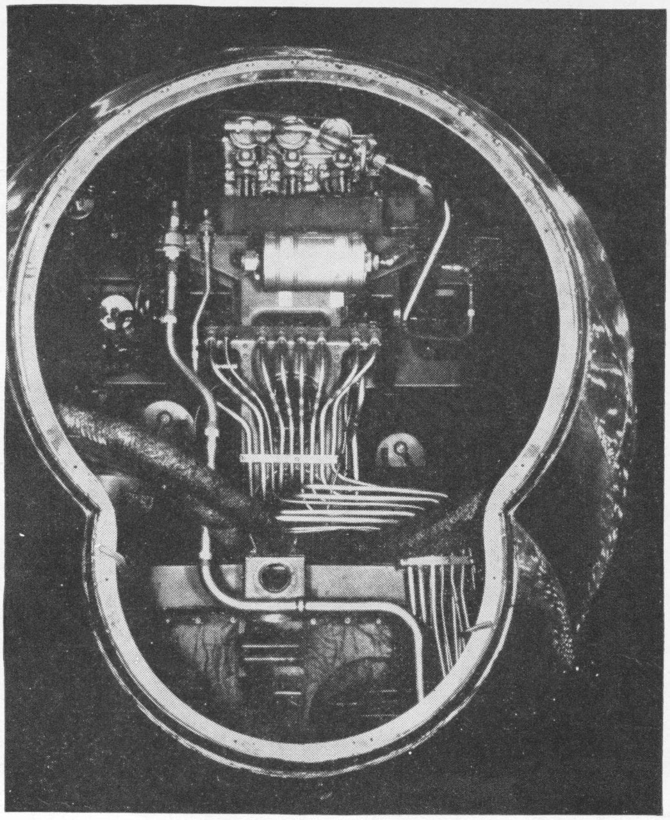


Fig. 5. The readily removable tip of the fuselage nose facilitates inspection and service of plumbing and wiring in back of the instrument panel. As a further aid to maintenance, the 25-odd engine, flight, and navigation instruments are grouped in four panels, any of which may be removed individually or as a complete unit.

De Havilland Mosquito

Two independent circuits—one the regular, the other an emergency—are contained in the hydraulic system used for operating the landing gear (1) of the Mosquito. Two hydraulic pumps are used, one on each engine. A hydraulic accumulator is provided in the aft part of the fuselage between bulkheads 3 and 4. Lines from engines to junction block in the cockpit, and from selector valve to landing gear jacks, run along the front side of the main wing front spar, where they are accessible when fairing over the radiator is removed.

An emergency landing gear "down" line runs along the aft side of the main wing rear spar. Hence, if the front lines are damaged, it is still possible to lower the wheels. A hand pump can be used for this purpose if engine pumps are not usable.

The emergency selector valve just behind the pilot's seat cuts in the emergency line. This line does not connect with the tail wheel, and the ship has to land without its being lowered. However, the damage sustained would be minor compared with a belly landing.

The main gear and tail wheel selector lever is centered in the hydraulic control box in the cockpit. A safety catch must be released before the UP position can be selected. The selector valve should return automatically to neutral when up or down operation is completed. If it should return prematurely, it is put down again by hand. This is possible in cold weather because of the great viscosity of the hydraulic fluid.

The 8.00- by 5.00-in. tail wheel is on a retractable unit having a vertical trunnion. Like the landing gear legs it has a rubber-type shock absorber. The wheel is mounted on a hinged fork attached to a caster swivel. Load is transmitted from the hinged fork to rubber elements in a swivel cylinder by a link and piston rod. Shock-absorbing elements are carried in a steel cylinder on needle bearings inside the shock absorber casting on the rear fuselage bulkhead. The jack ram is connected to the casing through a link which retracts the locking pin before it starts to raise the tail wheel.

Operated through a flat spring, a micro switch contacts the tail wheel casing when it is in the DOWN position and closes the circuit to the indicator on the instrument panel. No indication is provided when the tail wheel is up.

The shock-absorbing unit has six rubber blocks for cushioning purposes and one between the shock absorber piston and the bearing block to take the rebound.

The outer casing is a magnesium casting in which the shock absorber cylinder rotates. The cylinder is supported on the head end by a plain bearing and at the lower end by a needle roller bearing so that there is no wear on the softer magnesium. The top plate or cylinder head bears against a bakelite thrust ring when the shock absorber is in action. This top plate carries a V-shaped centering cam. An-

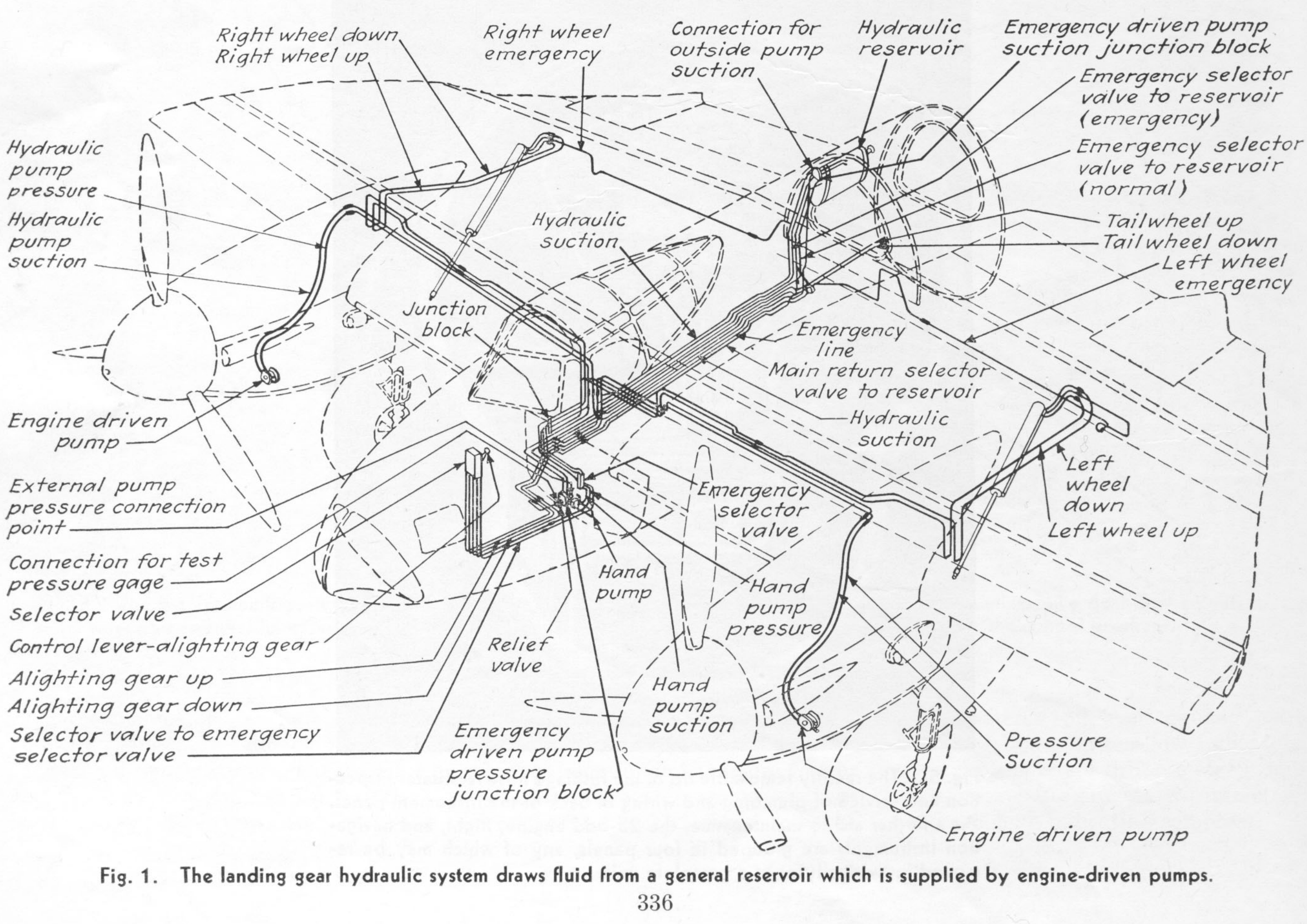


Fig. 1. The landing gear hydraulic system draws fluid from a general reservoir which is supplied by engine-driven pumps.

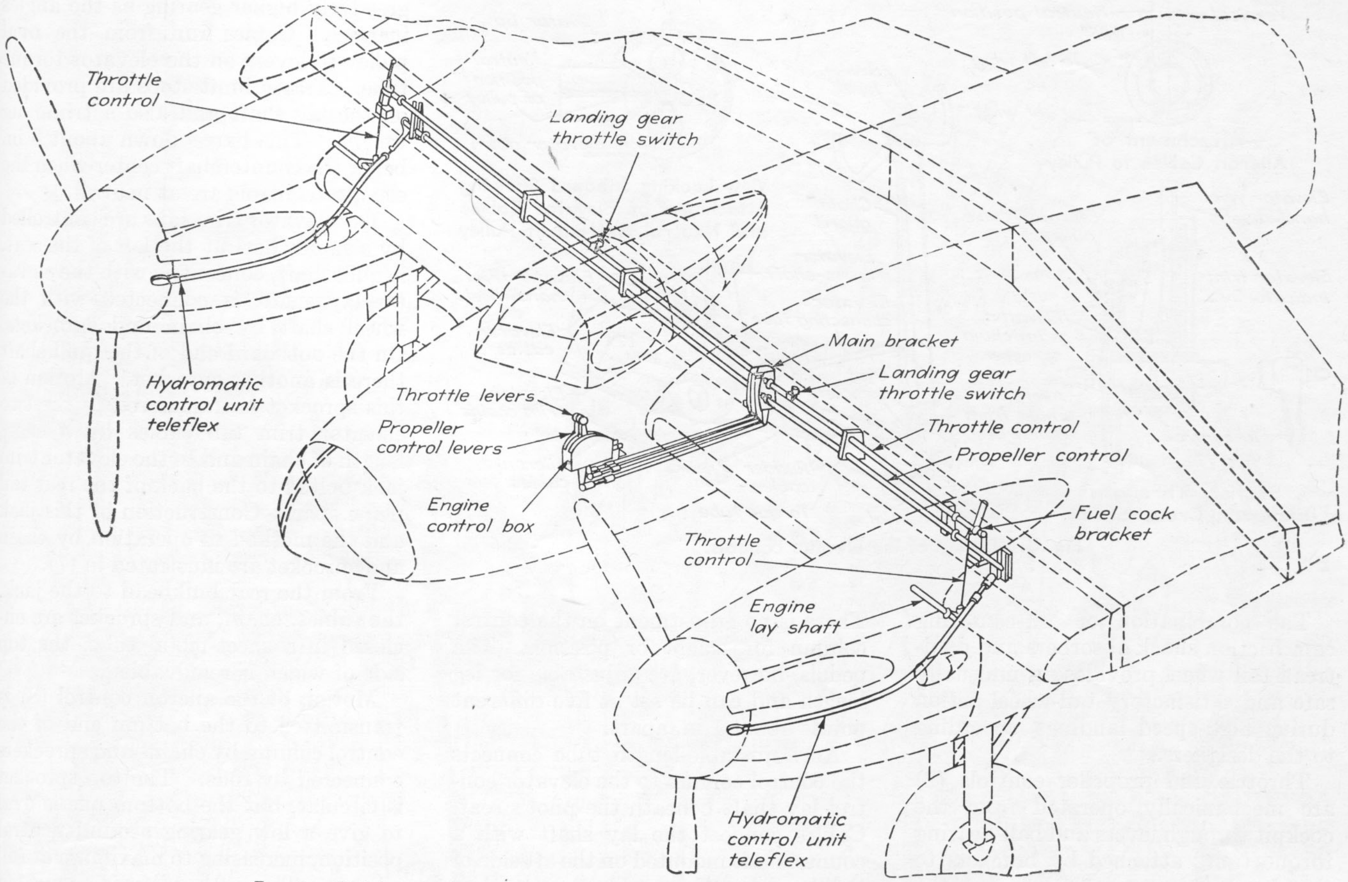


Fig. 2. Teleflex hydromatic propeller controls and tubular control for engine throttles.

other cam that does not rotate is located in the head of the casing and spring pressed against the V cam on the cylinder to center the tail wheel in flight. The cylinder is held in place by a hollow bolt through the center and supported by a ball thrust bearing.

The shock absorber piston is guided by a bearing block inserted at the bottom end of the cylinder. The method of locking the fork attachment to it with dowel pins is interesting. These pins are held in place by a band with notched holes that slip into a groove under the head of each dowel pin.

The cylinder and inner sleeve are fastened to the fork attachment by countersunk bolts.

Adjustable friction disk vibration dampeners are applied to the hinge shaft of the fork attachment. A rubber compression ring is used to adjust their tension. The tail-wheel assembly on the rear bulkhead is pivoted on two bearings located as far apart as possible and supported by a tube. This tube prevents their binding under severe twists. Laminum shims in the supporting bracket bushings permit axial adjustment of the tail-wheel assembly so the locking pin will align with the locking ring in the rear bulkhead.

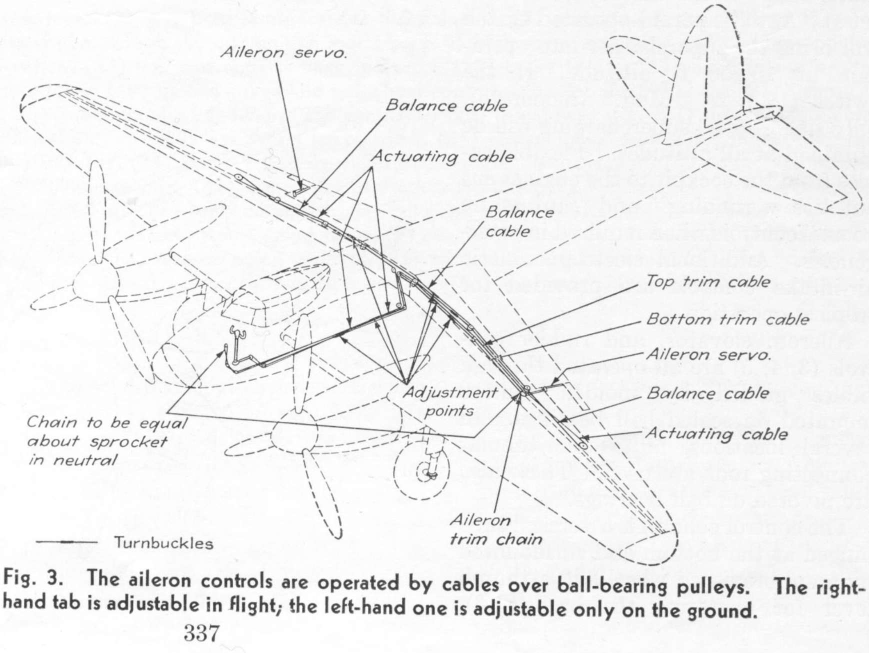


Fig. 3. The aileron controls are operated by cables over ball-bearing pulleys. The right-hand tab is adjustable in flight; the left-hand one is adjustable only on the ground.

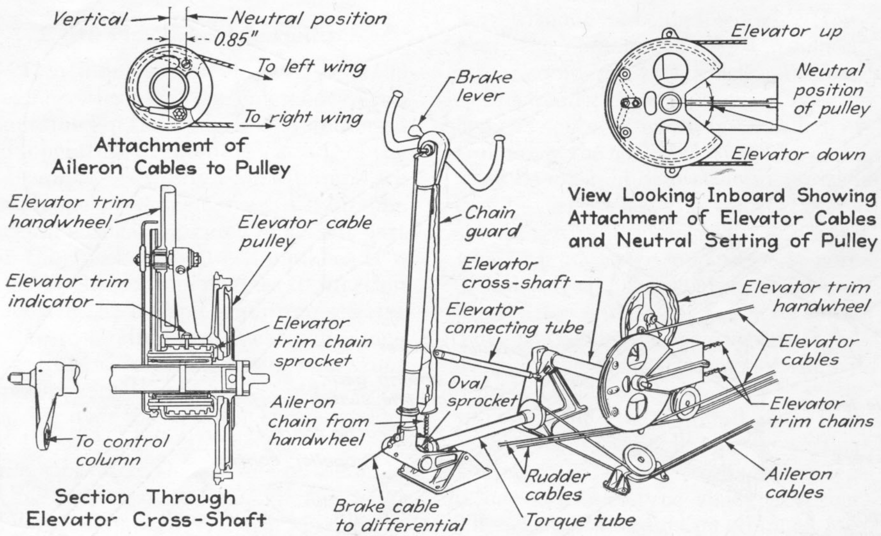


Fig. 4. Details of the elevator controls.

The combination of self-centering cam friction shock absorbers and dual-tread tail wheel provides an unusually safe and satisfactory tail-wheel action during high-speed landings, according to the designers.

Throttle and propeller controls (2) are mechanically operated from the cockpit through levers and ball-bearing torque tubes attached by brackets to the front-wing spar. Cams on the throttle torque tubes operate landing gear warning lights and horn switches when the throttles are more than three-quarters closed.

A two-speed supercharger on each engine is controlled by an electropneumatic ram. With the cockpit switch set at "Auto," aneroid-operated switch will bring the supercharger into operation at 15,250 ft altitude. If the switch is set at "Mod." (moderate), only single-speed supercharging will be obtained at all altitudes. Flexible cables from the cockpit to the engines cut out "slow running" and "automatic boost" controls when required in emergencies. Additional electropneumatic air-intake controls are provided for tropical operation.

Aileron, elevator, and rudder controls (3, 4, 5) are all operated through cables guided by molded pulleys mounted on sealed ball bearings. In several locations, adjustable tubular connecting rods are used. These also are pivoted on ball bearings.

The control column is a vertical tube hinged at the bottom and surmounted by an abbreviated wheel and a thumb lever for operating the brakes (6). There is no adjustment on the control column for height or position. The pedals, however, are adjustable for leg length and can be set at five different points about 1 in. apart.

An adjustable-length tube connects the control column to the elevator control lay shaft beneath the pilot's seat. Cables connect the lay shaft with a countershaft mounted on the aft side of bulkhead 4. These cables are attached to circular pulleys at both ends. The second elevator pulley on the countershaft is oval so as to provide a low gear ratio at small control angles with a progressively higher gearing as the angles increase. Cables run from the oval pulley to levers on the elevator torque tube. Travel limit stops are provided on the lay shaft and also a trimming weight. This hangs down about 6 in. below the countershaft center when the elevator controls are at neutral.

The elevator trim tabs are controlled by a handwheel at the left of the seat. A quill shaft, concentric with the elevator lay shaft, is connected with the wheel shaft by chain and sprockets. On the outboard end of the quill shaft there is another sprocket. Motion of this sprocket is transferred to the two elevator trim tab cables by a short length of chain and to the elevator trim jack bolted to the back of the rear tail plane spar. Construction of this jack and the method of operation by chain and sprocket are illustrated in (7).

From the rear bulkhead to the jack, the cables, chain, and sprocket are enclosed in a sheet-metal tube, the top side of which is removable.

Motion of the aileron control (8) is transmitted to the bottom end of the control column by chains and sprockets connected by rods. The top sprocket is circular, but the bottom one is oval to give a low gearing around neutral position, increasing to maximum at full aileron. The oval pulley is connected to a pulley beneath the seat by a tubular torque shaft. To allow for movement of the control column, a universal joint is provided in the torque-

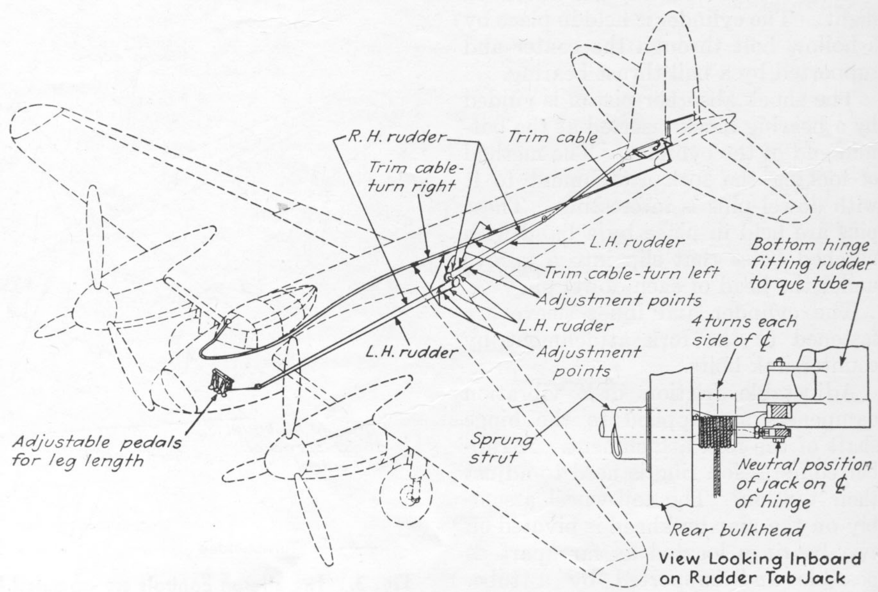


Fig. 5. Rudder control cables with adjusting turnbuckles indicated.

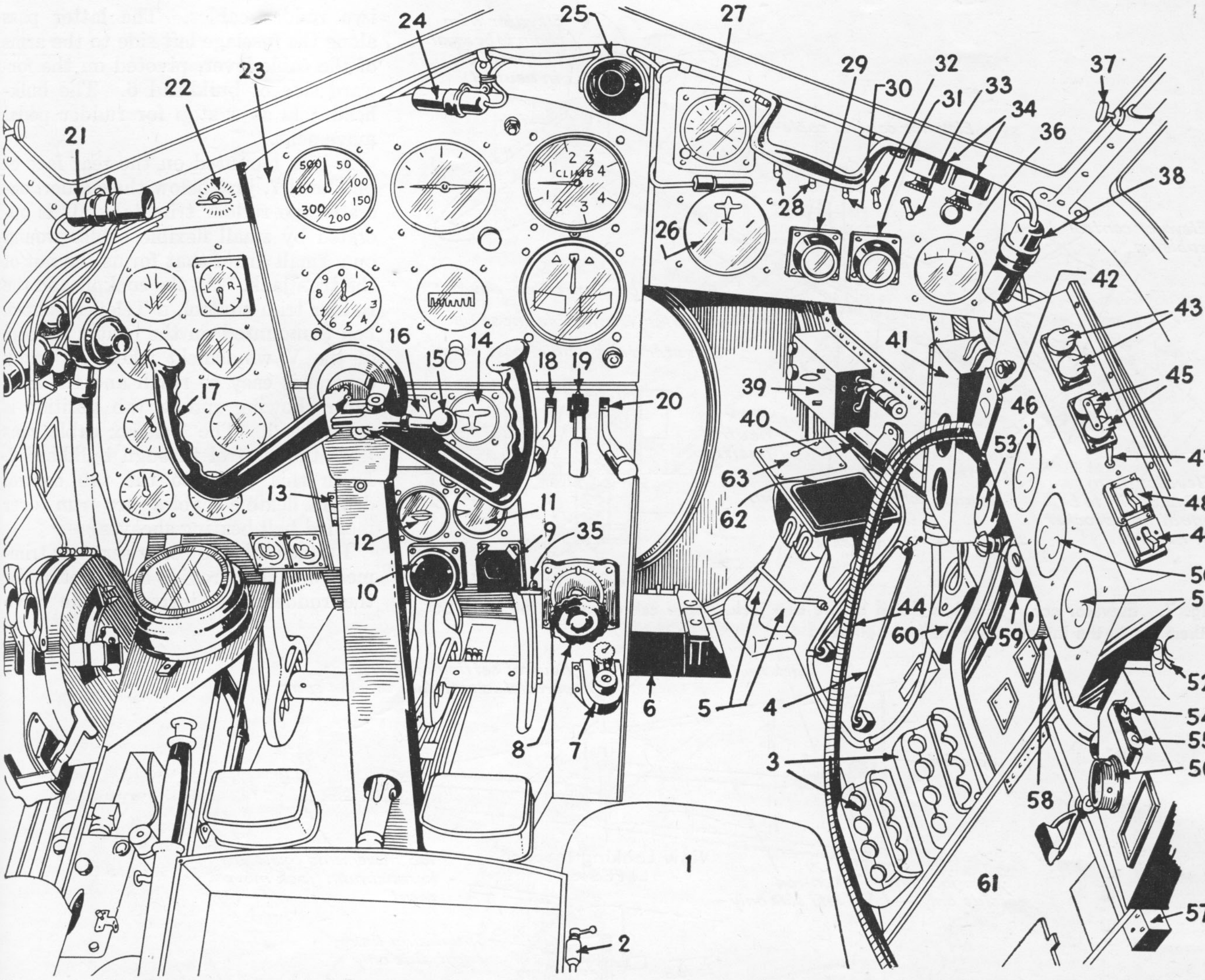


Fig. 6. (1) Front entrance door; (2) harness release lever; (3) very light cartridges; (4) Syko storage; (5) portable oxygen bottles; (6) bomb-sight base; (7) deicing hand pump; (8) aileron lateral trim control; (9) aileron trim indicator; (10) brake-pressure gauge; (11) oxygen-contents gauge; (12) oxygen-flow indicator; (13) master switch; (14) flap and undercarriage indicator; (15) brake lever; (16) undercarriage position indicator; (17) handwheel; (18) bomb door control lever; (19) undercarriage and tail-wheel control; (20) flap control lever; (21) lamp; (22) automatic boost cutout control; (23) blind-flying instrument panel; (24) lamp; (25) ventilator; (26) visual indicator; (27) time of flight clock; (28) radiator flap switches; (29) feathering control switch, left; (30) navigation lamp switch; (31) feathering control switch, right; (32) fuel-pump switch; (33) pilot head switch; (34) dimmer switches; (35) bomb jettison switch; (36) air-temperature gauge; (37) direct-vision panel knob; (38) air observer's lamp; (39) fuse box; (40) fireman's ax; (41) camera-temperature indicator; (42) voltmeter; (43) fire-extinguisher switches; (44) navigator's oxygen tube; (45) push switches; (46) fuel-contents gauge, outer tanks; (47) switch; (48) navigation head lamp switch; (49) downward identification lamp switch; (50) fuel-contents gauge, center tanks; (51) fuel-contents gauge, inner tanks; (52) downward identification lamp switch; (53) oxygen demand regulator; (54) booster pump switches; (55) recognition light switch; (56) watch holder; (57) power socket; (58) oxygen-contents gauge; (59) oxygen-flow indicator; (60) camera stowage; (61) navigator's hinged table; (62) elbow rest; (63) writing tablet.

tube attachment casting. The pulley on the end of the torque tube operates two aileron control cables, which pass down the left side of the fuselage to the rear face of the rear main spar and thence over ball-bearing molded pulleys to the aileron differential pulley.

Both ailerons have geared balance tabs. The right aileron tab adjustment is fixed during flight (although adequate adjustment is provided when trimming on the ground), but the left trim tab can be positioned during flight. The control with its indicator is at the lower right-hand corner of the instrument board. This operates with a sprocket and chain connected to control cables taking the same path as the aileron control cables. On the wing a chain and sprocket connection is provided to operate a screw and nut type of trim jack.

The empennage controls (9) consists of adjustable rudder pedals which are hung from two parallel overhead shafts, the right pedal being suspended from the front one. Two arms on each side of the pedal pad are provided. Each shaft has an arm almost as long as the pedal that is connected to one of the

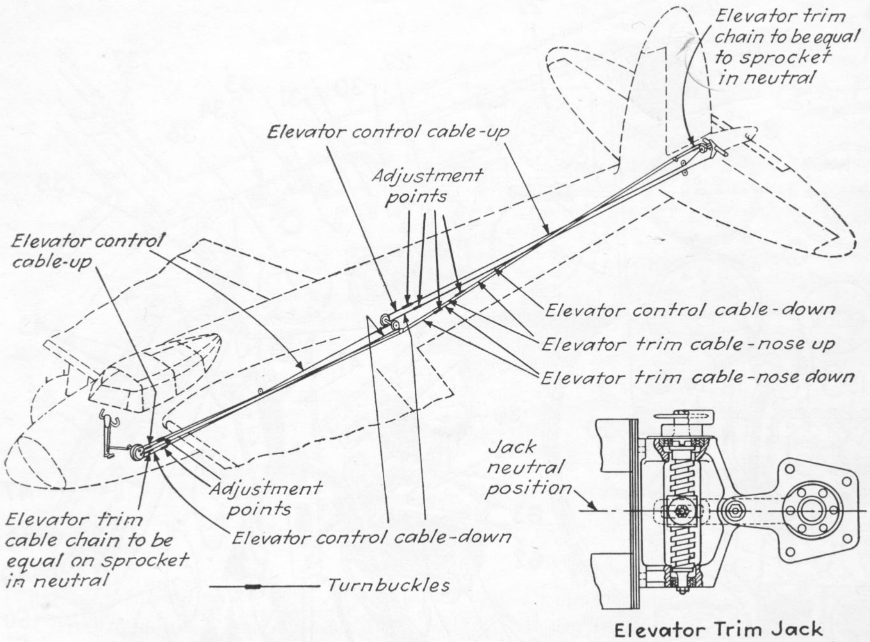


Fig. 7. Elevator controls with a detail of the trim jack. Trim cables run to the jack, but others run to the intermediate shaft of bulkhead 4.

two rudder cables. The latter pass along the fuselage left side to the arms of the cable lever, pivoted on the forward side of bulkhead 6. The bulkhead acts as a stop for rudder pedal movement.

A jack mounted on the rear face of bulkhead 7, just below the rudder, operates the rudder trim tab. It is operated by small flexible cables wound on a small drum that forms the nut of the trim jack. At the cockpit and the rudder trim control, a Teleflex control box is mounted on the center support of the V windshield where its crank control is easy to reach and the indicator showing rudder tab position is easily read. The Teleflex cable runs from the control through bulkhead 3. From this point to the tab control drum, flexible cables are run over molded ball-bearing sheaves.

Rudder tabs not only serve as trimmers but also provide servo action for the rudder. To introduce the servo

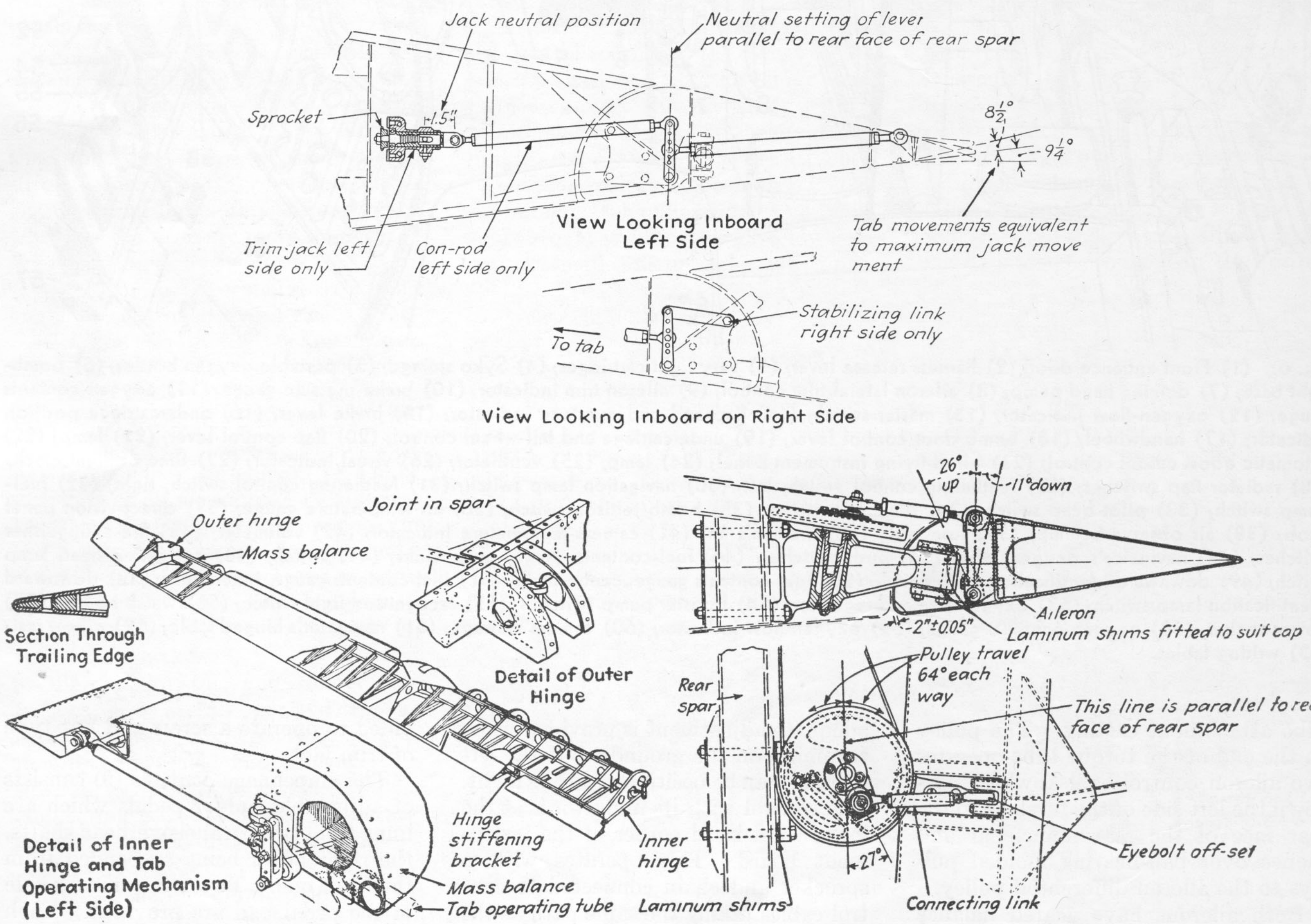


Fig. 8. An aileron, with outer and inner universal hinges and center hinge on the differential control bracket; also trim tab controls and the method of operating.

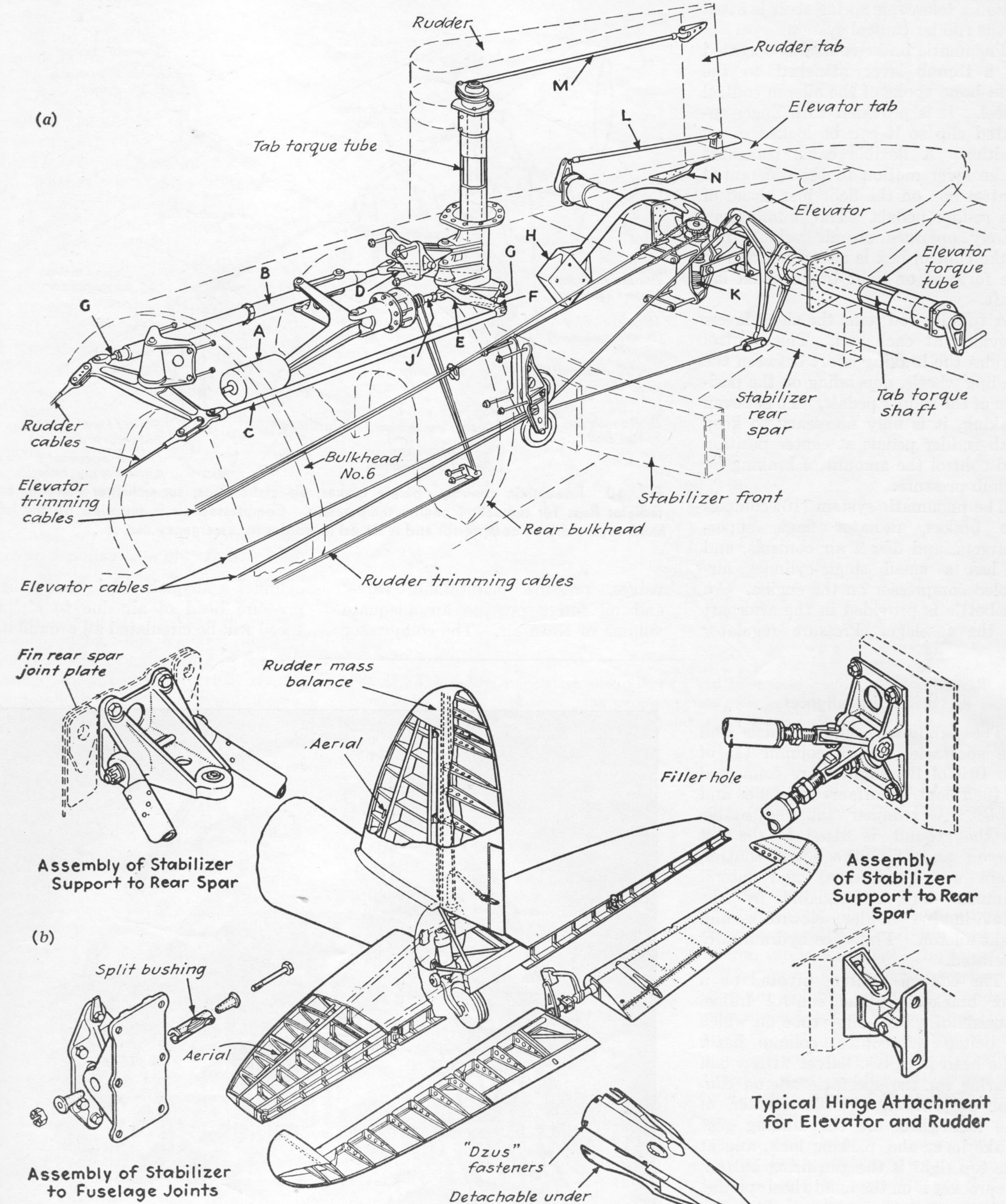


Fig. 9. (*a*) Empennage and controls, with details of the fastenings and the method of transmission; *A*, rudder static balance; *B*, telescopic strut (also shown in the enlarged detail); *C*, connecting rod; *D*, rudder lever; *E*, link lever; *F*, servo lever; *G*, link; *H*, elevator static balance; *J*, rudder trim jack; *K*, elevator trim jack; *L*, elevator tab connecting rod; *M*, rudder tab connecting rod; and *N*, rudder tab static balance. (*b*) Tail unit arrangement.

action a telescopic spring strut is fitted in the rudder control system.

Pneumatic brake control is operated by a thumb lever attached to the right-hand spoke of the aileron control wheel. It is provided with finger-operated clip so it can be locked in ON position. A flexible cable transmits brake lever motion to the differential control box on the floor just ahead of the rudder pedals. The thumb lever merely operates an air valve. The brake control box is also connected to the forward or right brake pedal lay shaft.

A tubular rod joins the short levers provided at each end. This control divides the braking effort between the landing wheels, depending on the position of the rudder pedals. To get even braking, it is only necessary to keep both rudder pedals at center position and control the amount of braking by thumb pressure.

The pneumatic system (10) controls the brakes, radiator flaps, superchargers, and desert air controls, and it has a small single-cylinder air-cooled compressor on the engine. An air bottle is provided in the afterpart of the fuselage. Pressure regulator valves, pressure maintaining valve, and oil filters provide an adequate volume of clean air. The compressor cylinder is air-jacketed so that a high-pressure head of air due to aircraft speed will be circulated all around it.

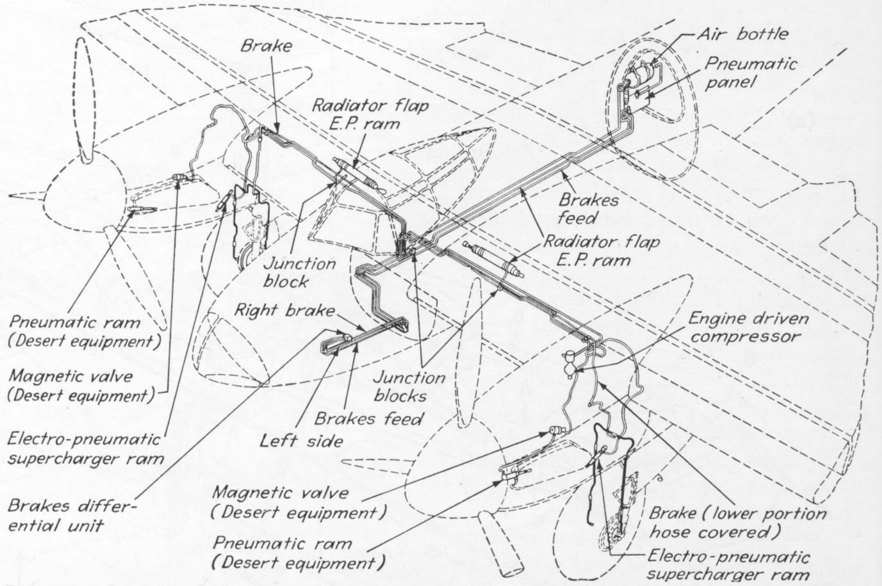


Fig. 10. Pneumatic controls operate brakes, air-intake flaps, supercharger controls, and radiator flaps for regulating engine temperature. Compressed air is supplied by the left-hand engine-driven compressor and is stored in bottles for emergency use.

Bristol Beaufighter

The pendulum rudder pedals and the spectacle control column (1) of the Bristol Beaufighter are connected to their control surfaces by chains and cables. A trimmer tab, adjustable on the ground, is fitted to the left aileron and, for directional control, there are longitudinal and lateral trimmer tabs controllable by the pilot in the rudder, elevators, and right aileron. Flaps are hydraulically operated.

The control column, pivoted on a box bracket on the control frame, consists of a light-alloy tube on which is bolted the control column head. The head is in two halves with a ball bearing for the spectacle aileron control handwheel. At the center of the handwheel are the landing gear brake lever and parking lock, and at the top right is the gun firing button. A sprocket is on the handwheel spindle, and from it a chain extends down the control column and over two ball-bearing pulleys on the mounting bracket behind the column pivot.

A socket on the bottom of the control column is secured to spigots pivoted

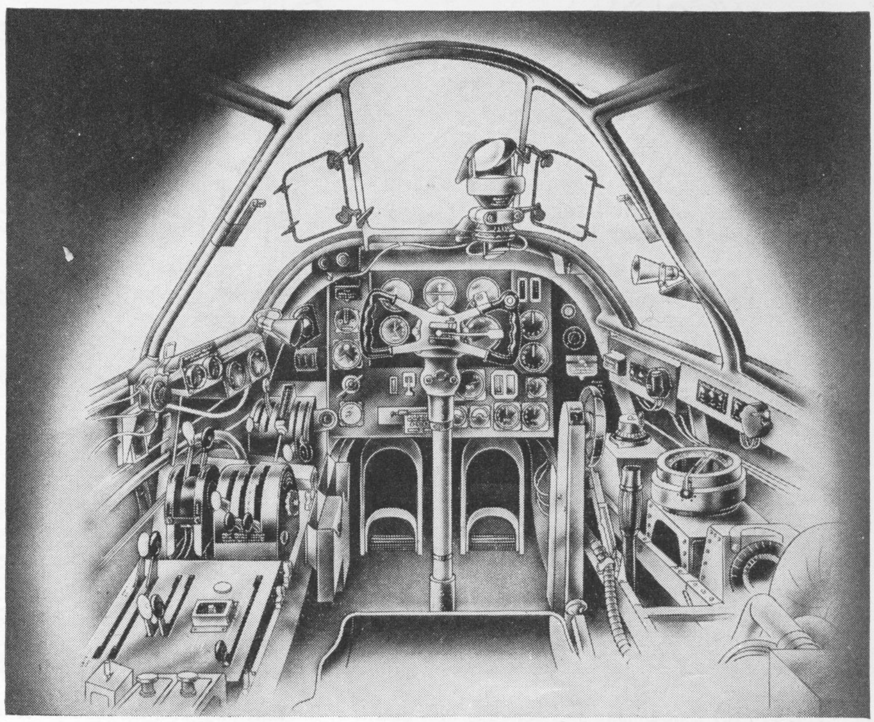


Fig. 1. The pilot's cockpit seen from the seat. A gun-firing button on spectacle-shaped steering wheel. Blind flying instruments are directly in front of the wheel, while trim tab controls and compass are on the right and engine and hydraulic controls on the left.

on ball bearings in the mounting bracket. The elevator control lever, riveted to the socket and spigots, extends below the mounting bracket. Adjustable stops are at the forward and after ends of the bracket.

Rudder pedals (2) pivot on a transverse support tube between the sides of the fuselage and are of stirrup form with leather toe straps. Each pedal lever, near mid-length, is connected by a link to a lever turning a vertical countershaft, at the bottom of which is an outboard-pointing lever. For leg-reach adjustment, the two levers at the top of the countershaft are fixed to a sliding trunnion which can be moved backward by a crank below the instrument panel to give 3-in. adjustment to the pedals, either side of normal.

From the lever at the bottom of the control column, one cable passes forward and around a pulley on the rudder and elevator torque tube; another passes aft to a pulley assembly (mounted on the control frame) and then to a pulley assembly on the front keel member forward of the front spar (3). From there the cables, with turnbuckles at the rear hatch, extend inboard along the left keel member over pulleys aft of the crate in the rear fuselage to a central vertical double countershaft in the stern frame carrying the ball-bearing elevator levers for rudder control.

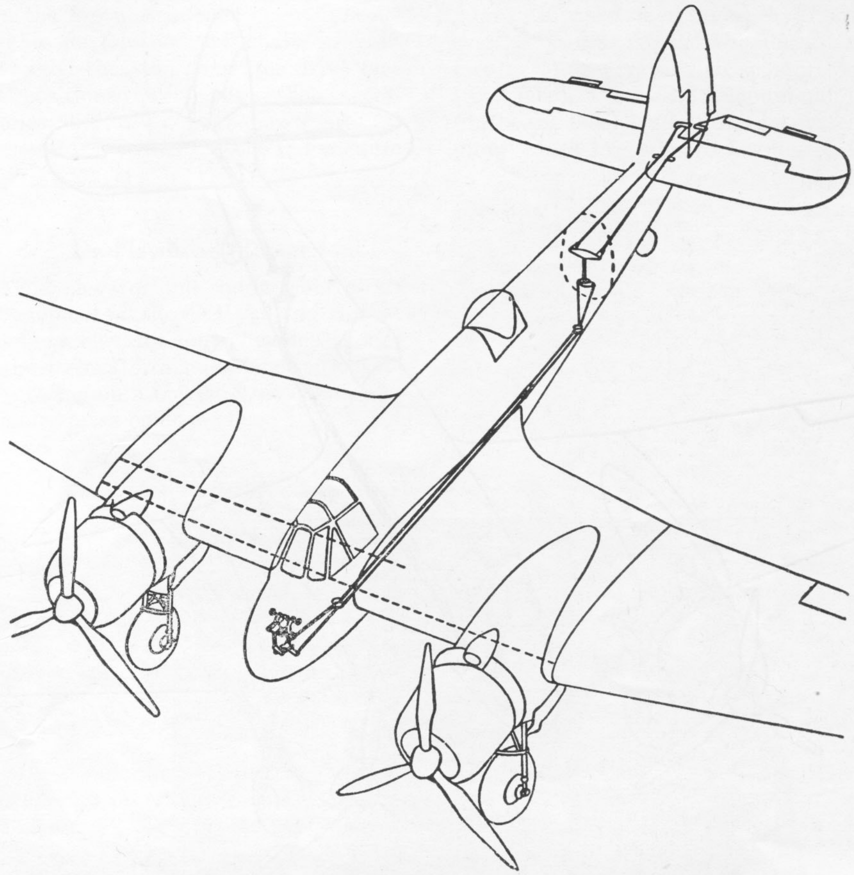


Fig. 2. The rudder pedals are stirrup-shaped and hang from a cross member beneath the blind flying instrument board. The pedals operate a vertical countershaft, from which cables run aft to another vertical shaft. From this point cables lead directly to the rudder.

From this countershaft, movement is transmitted by an adjustable connecting tube to a horizontal countershaft and to the elevators by an adjustable connecting tube to which the horns for the elevators are secured by a special bolt. From the lever at the bottom of the rudder pedal vertical countershaft, movement is transmitted by a connecting tube to the rudder and elevator torque tube, thence by a cable to the stern frame countershaft from the top of which cables, with turnbuckles at the levers, lead over pulleys to the rudder horn.

Aileron control chains at the foot of the control column are connected by another chain to a sprocket on the aileron relay post aft of the control frame just forward of the front spar. Chains and cables extend outboard from the four quadrants over sprockets and pulleys (on the front face of the front spar) to a point between ribs 11 and 12, where their directions turn toward the aileron (4). Turnbuckles for adjustments are fitted between the control column and the relay post, also just outboard of the outer and center wing joints. A telescoping conduit encloses the chains and cables between the spars. The final chain passes over the sprocket behind the rear spar and around a sprocket on the differential gear.

Two special tail ribs behind the rear spar support the aileron differential gear. This consists of a sprocket on the inboard tail rib which has an integral differential lever that is connected by a link to the aileron horn.

A lever on the outboard tail rib also supports the connecting link. The top pivot point of the connecting link in the neutral position of the aileron is mounted above the horizontal line through the sprocket center so that, for the same rotation on either side of neutral, the vertical movement of the pivot point and the angularity of the aileron are greater when the aileron is being raised than when lowered in flight.

Trimming tab controls for tabs in the trailing edge of the elevators and rudder are controlled from the right side of pilot's cockpit by cables and chains connecting to actuating units at the stern frame. The trimming tab on the left aileron can be adjusted only when on the ground, but the right aileron tab is controllable by the pilot.

The elevator tab control wheel is atop the column on the right side of pilot's cockpit, and it operates (by a chain) a drum at the bottom of the column from which cables extend along the right keel member to just forward of the tail wheel. Here the cables are connected by turnbuckles to chains (on later models, Teleflex cables) that operate a drive unit behind the stabilizer rear spar, whence flexible drives go to a screw jack or actuator at the inboard end of each elevator and coupled directly to the tab horn by an adjustable rod. An indicator is mounted partly on the starboard shelf and partly on the aft side of

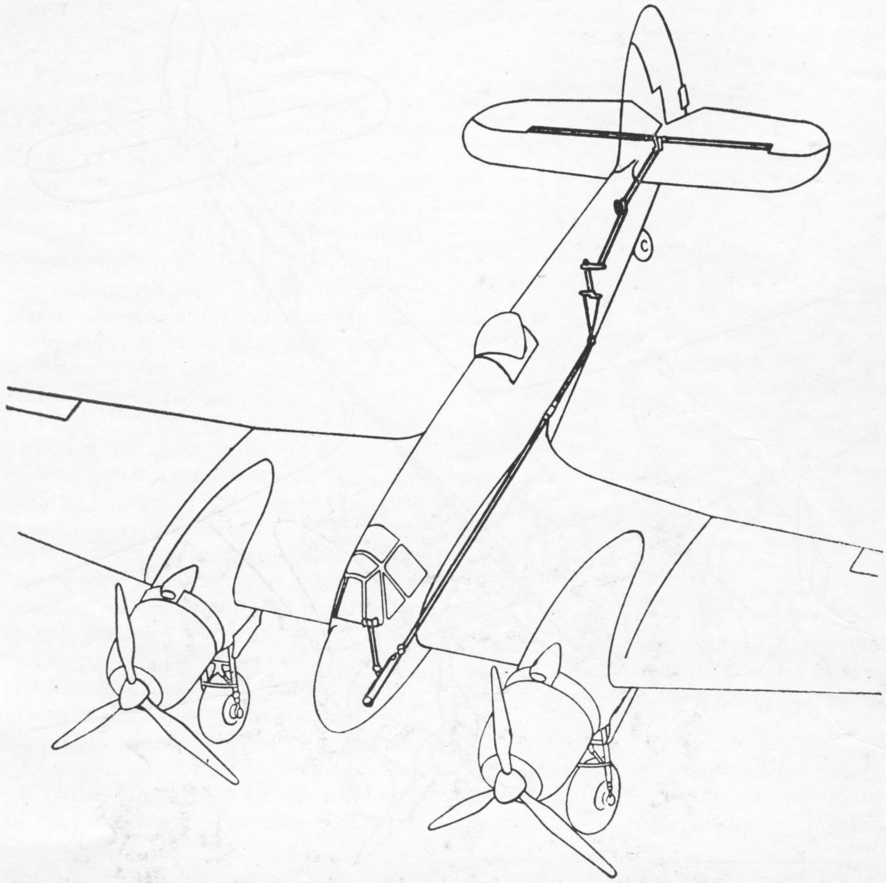


Fig. 3. Elevator controls extend aft along the left keel member to the central vertical countershaft, from which motion is transmitted through tubular connections to the elevator horns.

the column supporting the handwheel.

The rudder tab control handle with indicator is mounted on the right shelf in the pilot's cockpit and is connected by a bevel wheel and torque shaft to a drum from which cables and chains (Teleflex cables on later models) connect to a drive unit from which a flexible drive operates an actuator coupled to the tab horn by an adjustable rod.

The aileron tab control handle with indicator is mounted on the right shelf in the pilot's cockpit in line with the seat back and is connected by cable to a pulley and sprocket (on the rear face of the rear spar, right side) whence cables and chains drive an actuator mounted between the aileron spar and coupled to the tab horn by an adjustable rod.

The two flaps on each side of the main plane are operated by a hydraulic jack pivoted on the rear face on the rear spar inboard of the center and outer wing joint. The piston rod of the jack is coupled to the bottom of a quadrant pulley on a support frame behind the rear spar, with two links at the top of the pulley connected to the operating levers of the flaps. A cable round the quadrant pulley is connected by chain to a small sprocket on a relay shaft farther inboard. From the large sprocket on the relay shaft, chains and cables extend across the center plane and interconnect the flaps on each side so that they are raised and lowered simultaneously.

A lever for flap control is on the left side below the instrument panel. An indicator, showing flap position, is connected by Teleflex controls to a lever on the flap hinge at the left side of the fuselage.

Mounted on the left side of the cockpit are throttle, mixture, propeller speed, supercharger, and air-intake controls. Carburetor cutout controls are mounted on top of the front spar, on the left side of the cockpit under a spring-loaded cover. Cowling flap switches are mounted on a sloping panel between the engine control shelf and the carburetor cutout box.

Throttle and mixture levers are connected to rods in the engine nacelles by push-pull rods and torque tubes in Oilite and ball bearings along the nose of the wing. Carburetor cutout knobs and the air-intake, propeller and supercharger control levers are

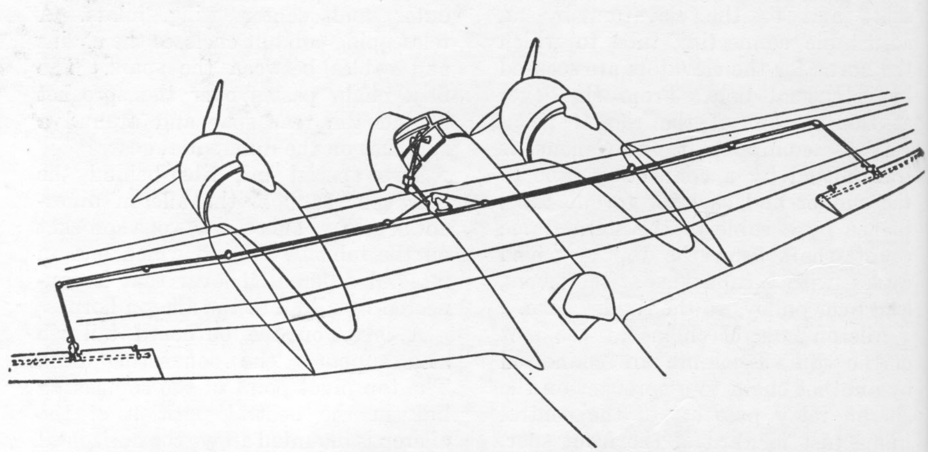


Fig. 4. Aileron controls operate through chains from the steering column to the control frame forward of the front spar. Chains and cables extend outward and turn around pulleys toward the ailerons. From pulley to aileron differential gear, controls pass through a telescopic casing. Final control is from the differential gear to the aileron horns.

connected to their respective engine levers by Teleflex controls. The cowling flap switches operate electric motors mounted on the righthand side, looking aft, of the engine nacelle.

An auxiliary gear box is mounted on the fire wall in each engine nacelle by a flexible jointed shaft so constructed that the generator drive face is positioned vertically. The accessories driven by gear boxes are (*a*) generator (top face), Pesco B.3 vacuum pump (inboard face), and hydraulic system pump Mark IV (outboard face); (*b*) generator, air compressor (rear face), Pesco B.3 vacuum pump (outboard face), and hydraulic system pump Mark IV (inboard face).

De Havilland Hornet

The elevator and rudder control arrangement on the de Havilland Hornet includes elevator control cables, rudder cables, elevator mass balance sprockets operating on a bicycle-type chain, and rudder mass balance (1).

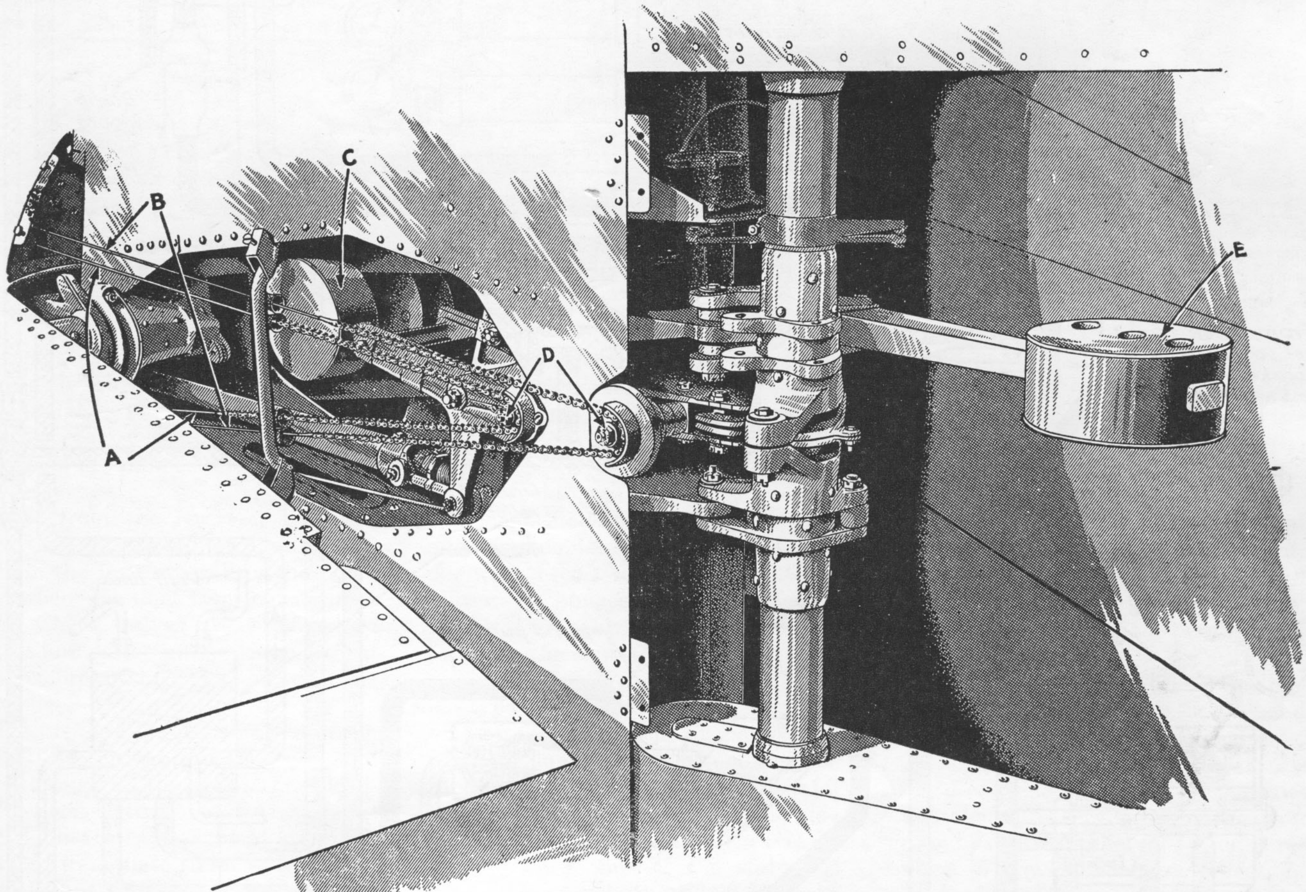


Fig. 1. De Havilland Hornet elevator and rudder control arrangement, showing elevator control cables (*A*), rudder cables (*B*), elevator mass balance (*C*), sprockets (*D*) operating on a bicycle-type chain, and rudder mass balance (*E*). While the main portions of the Hornet wing and fuselage are of wood construction, the empennage units are metal.

North American B-25 Mitchell

The hydraulic system (1) of the B-25—single-pressure type—operates the tricycle landing gear, wing flaps, cowl flaps, bomb-bay doors, and brakes. Cowl flaps have separate control handles for the left and the right engines, operation of either the cowl or the wing flap (2) may be stopped at any desired position.

A manually operated emergency hydraulic system permits actuation of the different subsystems should both engine-driven pumps fail, or when the plane is on the ground with the engines not operating.

The Pesco 349P hydraulic pumps are engine-driven, two-gear positive-displacement types with a pressure limit of 1,500 psi for continuous operation,

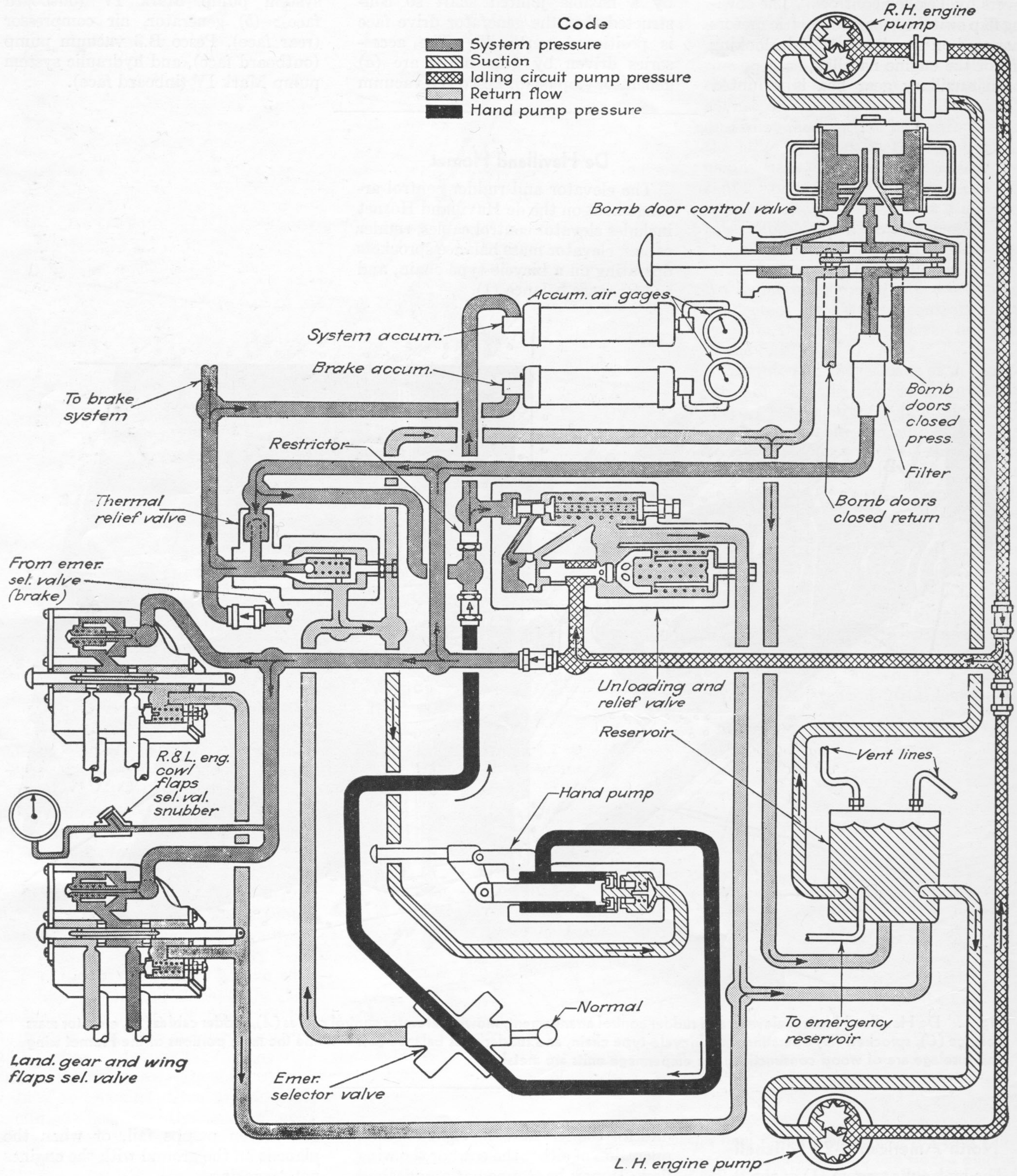


Fig. 1. Schematic diagram of the hydraulic system.

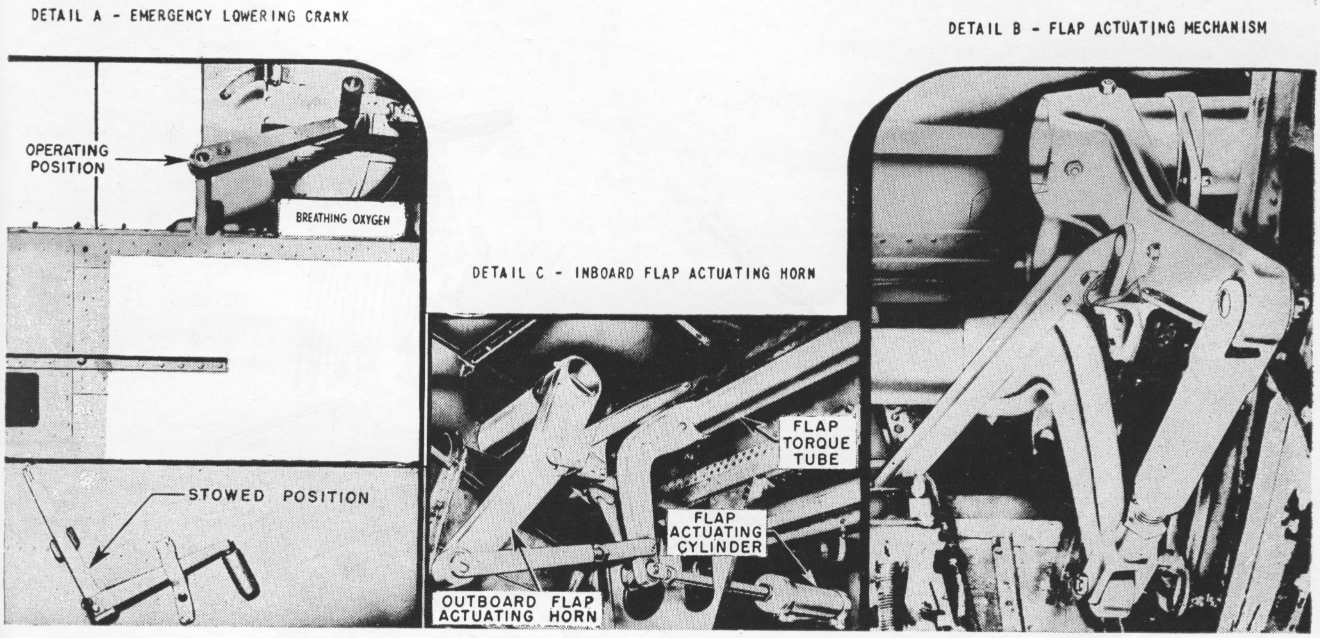


Fig. 2. Flap installation, showing details of the emergency lowering mechanism.

will operate in either direction, and are completely lubricated by the fluid passing through. They are located on the engine accessory sections, and either is capable of providing sufficient pressure for the system.

Fluid from the reservoir is forced from the pumps through lines routed back to the forward wall of the bomb bay, where the lines from both pumps join. Check valves are provided so that failure of one pump will not affect the pressure produced by the operating pump.

The pressure line continues on from a T fitting through a check valve and then through all the system lines leading to the selective operating systems.

A duplicate cable control system is installed to actuate rudders, elevators, and ailerons. Each system is so designed that loss, through gun fire, of any one cable will not seriously cripple the plane.

The cables are color-banded to facilitate assembly, repair, and inspection of the control system.

Control forces originated by the pilot are applied to the control column, located on the left side of the compartment, connected to a steel torque tube extending across the fuselage and having take-off horns at each end. Elevator cables extend aft along each side of the fuselage from control column horns to bell cranks in the aft fuselage. Adjustable push-pull rods connect each bell crank to the respective elevator horns.

The elevators are joined by a torque tube connected to each elevator horn and may be raised 25 deg or lowered 10 deg with respect to the horizontal stabilizer. A bungee is incorporated in the elevator control system to reduce forces on the control column.

The rudders are actuated by hanging-type pedals. Control cables extend aft along each side of the fuselage from the lower outboard ends of the rudder pedal assembly to the horizontal stabilizer, then outboard on each side of the stabilizer to rudder sheaves at the outboard ends of the stabilizer. The rudders can be moved 20 deg right or left with respect to the vertical stabilizers. The loss of cables on one side of the aircraft will not affect rudder control on the opposite side.

The ailerons are controlled by clockwise and counterclockwise movement of the pilot's control wheel. Cables are led out of the control column torque tube, then aft to the aileron sector on the rear wing spar. The maximum upward aileron movement is 28 deg, and 14 deg downward.

The elevator trim tab controls are operated by a control wheel on the left side of the pilot's control pedestal (3). Aileron trim tabs are actuated by the forward control knob on the floor of the cockpit, and the aft control knob on the floor operates the rudder tabs.

The main control quadrant and rod assembly, auxiliary control quadrant, right and left carburetor heat control rods, control pulley base, and throttle and mixture rod are on the pilot's upper control pedestal (4).

Nacelle engine controls (5) include throttle control lever, mixture control lever, propeller governor, etc.

B-25H and J electric systems are 24-volt, d-c, single-wire type with the aircraft structure serving as a common ground except where dual wiring is required to prevent compass deflection. Nearly all the wiring is of open type, supported by clips and protected, where necessary, by insulating tubing, tape, or cord. Conduits enclose wiring in the engine nacelles and wherever additional mechanical support or electrostatic shielding is necessary.

A 24-volt 34 amp-hr battery is located in each engine nacelle, aft of the fire wall. Either battery will operate the electric system, including starters.

Two engine-driven 200-amp 30-volt generators, one mounted on the supercharger housing of each engine, power

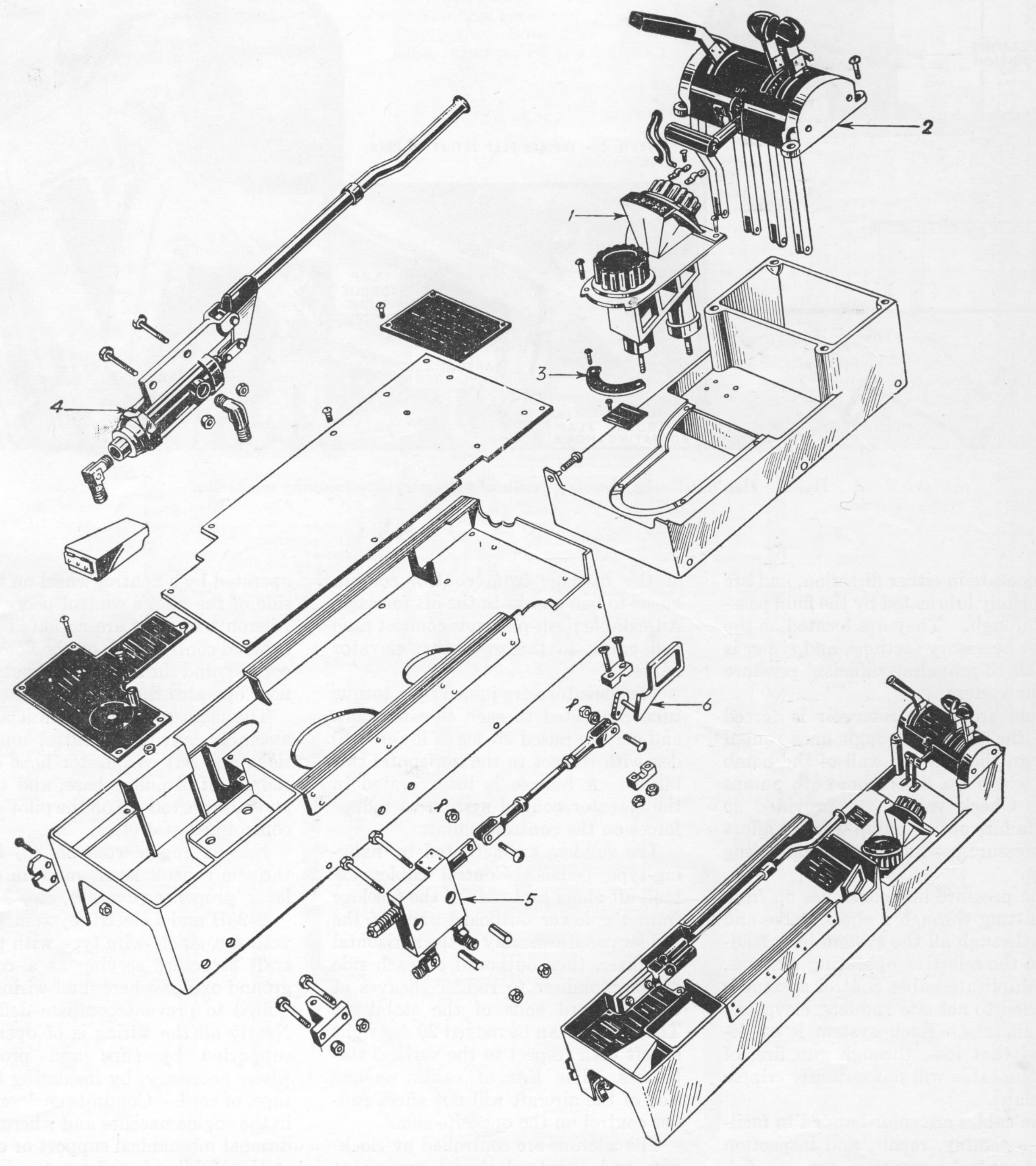


Fig. 3. Pilot's lower control pedestal: (1) aileron and rudder tab controls; (2) hydraulic control cap assembly; (3) rudder tab indicator plate; (4) hydraulic handpump; (5) pneumatic emergency brake valve; (6) pneumatic emergency brake handle. A complete pedestal is seen at the lower right.

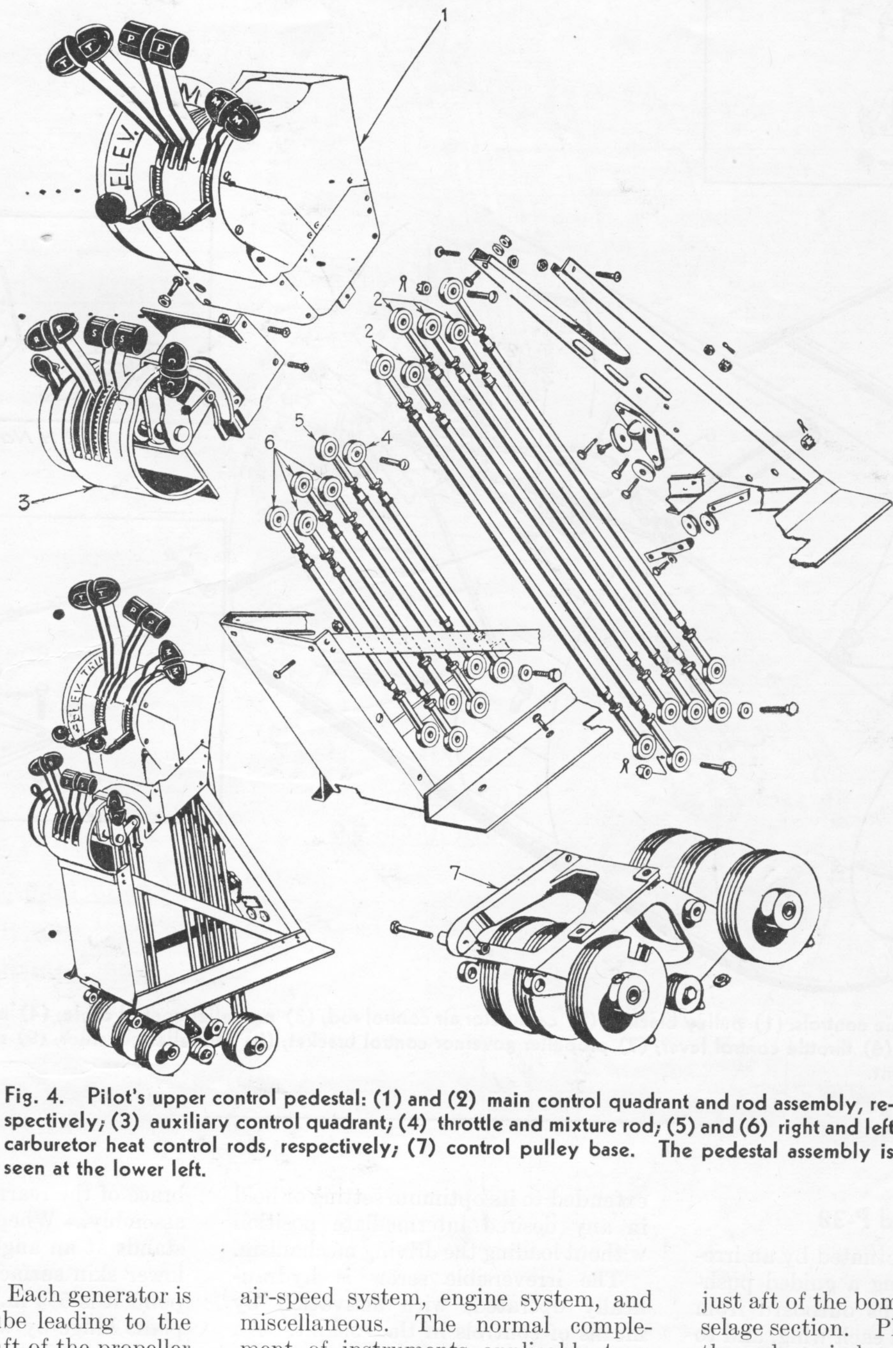


Fig. 4. Pilot's upper control pedestal: (1) and (2) main control quadrant and rod assembly, respectively; (3) auxiliary control quadrant; (4) throttle and mixture rod; (5) and (6) right and left carburetor heat control rods, respectively; (7) control pulley base. The pedestal assembly is seen at the lower left.

the electric system. Each generator is cooled by a blast tube leading to the generator from just aft of the propeller disk.

Instruments are divided into four general classifications: vacuum system, air-speed system, engine system, and miscellaneous. The normal complement of instruments applicable to a twin-engine bomber is utilized and offers no unusual installations.

A K-24 type camera is located just aft of the bomb bay in the rear fuselage section. Photographs are taken through a window in the fuselage floor, through a range of 50 deg fore and aft of vertical.

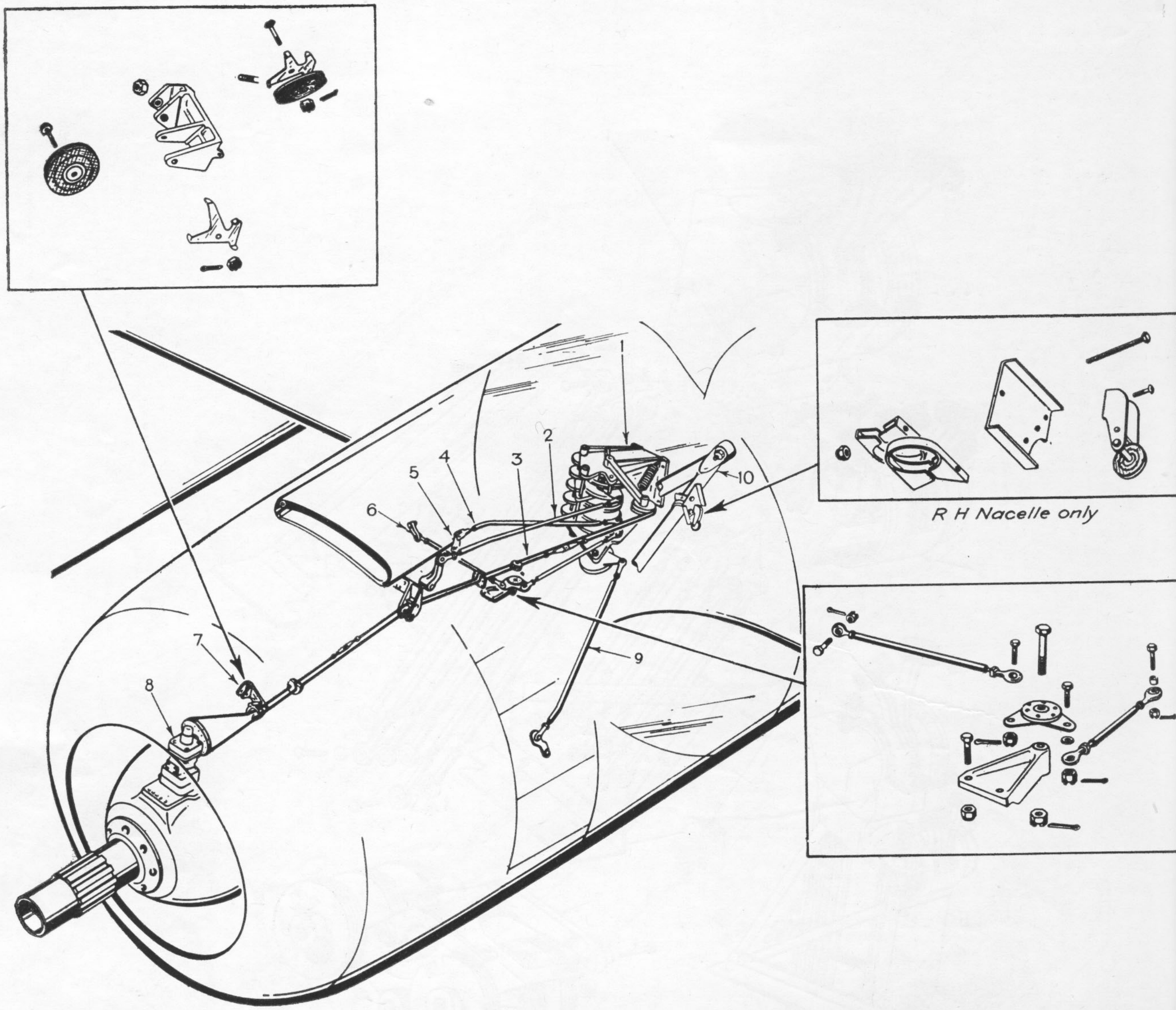


Fig. 5. Nacelle engine controls: (1) pulley bracket; (2) carburetor air control rod; (3) propeller control cable; (4) mixture control rod; (5) mixture control level; (6) throttle control lever; (7) propeller governor control bracket; (8) propeller governor; (9) supercharger air control rod; (10) engine mount.

Lockheed P-38

The P-38 flap is actuated by an irreversible screw driving a guided push-pull tube, which runs outboard from the fuselage through each wing, and to which the flap carriages are connected by means of a system of $\frac{1}{8}$-in. extra-flexible, preformed, tinned, carbon steel cables.

All pulleys and other rotating parts of the flap-actuating system (1) are mounted on antifriction-type bearings. This mechanism permits the flap to be extended to its optimum setting or held in any desired intermediate position without loading the driving mechanism.

The irreversible screw is hydraulically operated, with activation by means of controls in the cockpit. An auxiliary hydraulic hand pump provides operating power in case of failure or damage to the engine-driven hydraulic pump.

Actuation is electrical, with a high-speed electric motor driving actuating screw mechanisms connected to a curved arm hinged to a fitting on the brace of the rearmost panel of the fla assembly. When lowered, the fla stands at an angle of 40 deg from th lower skin surface line; at its farthe point it is $5\frac{1}{2}$ in. from the wing to th piano hinge by which it is attached t the brace panel.

Two actuating mechanisms, side b side at the center, operate each flap, th actuating arms swinging downwa through an opening in the wing skin.

The control system consists of rudd pedal hangers of the full stirrup typ and toe-type brake pedals, and half-

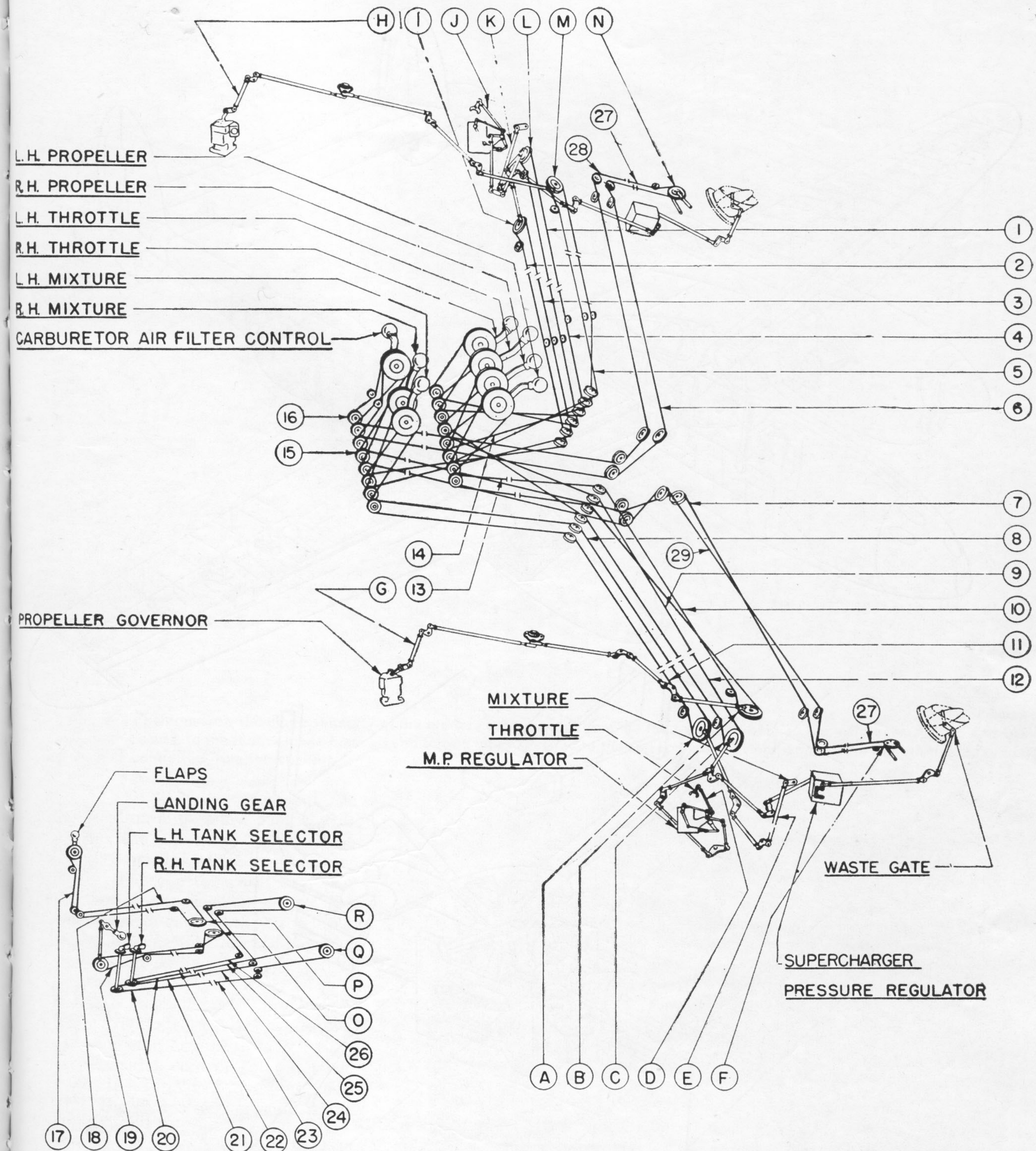


Fig. 1. Phantom view of the wing flap, landing gear, and engine control system showing: (1) right throttle; (2) and (3) right mixture; (4) right throttle; (5) right propeller; (6) right carburetor air, center; (7) left carburetor air, center; (8) left mixture; (9) left throttle; (10) left propeller; (11) left mixture; (12) left throttle; (13) left propeller; (14) right propeller; (15) and (16) left and right carburetor air forward; (17) and (18) fore-and-aft flap four-way valves; (19), (20), and (21) left and right tank selectors; (22) right tank selector; (23) left selector; (24) right tank selector; (25) left tank selector; (26) right tank selector; (27) left and right carburetor air, aft; (28) and (29) right and left carburetor air, center; (*A*), (*B*), and (*C*) pulley bracket assemblies; (*D*) allison rod, left throttle; (*E*) rod, left mixture; (*F*) pulley bracket assembly; (*G*) and (*H*) rods, left and right propeller governors; (*I*) pulley bracket assembly; (*J*) allison rod, right throttle; (*K*) rod, right mixture; (*L*), (*M*), and (*N*) pulley bracket assemblies; (*O*) pulley; (*P*) pulley assembly; (*Q*) and (*R*) drums.

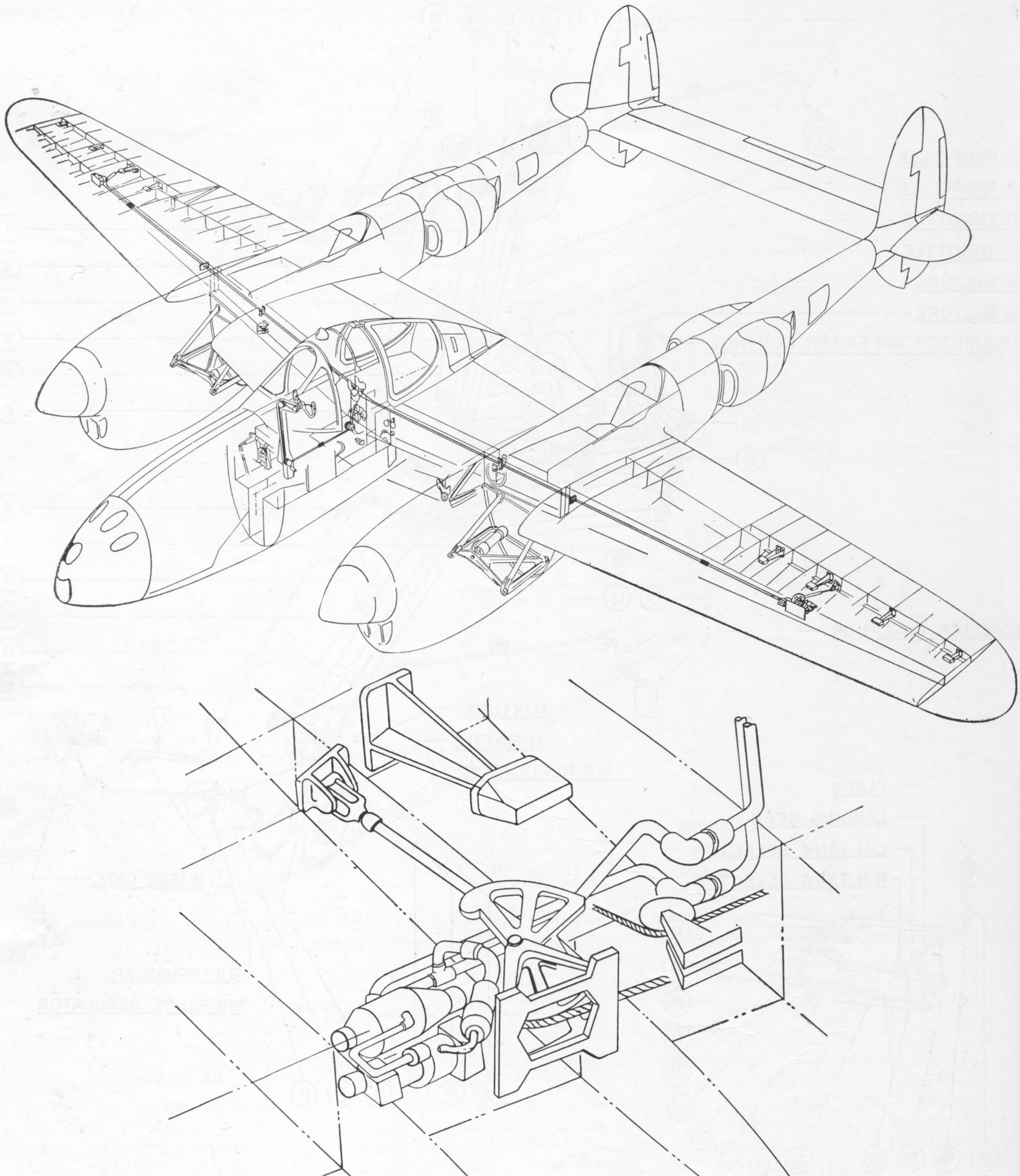


Fig. 2. This phantom view shows aileron control cables leading from the control column back to the drum assembly on the main beam and out to boosters used to overcome pressure on the ailerons due to high speed. The pilot supplies only one-sixth of the force necessary to actuate the ailerons; booster, utilizing main system hydraulic pressure, supplies additional force required. Force from the control cable on the booster quadrant is transmitted to the bell crank and push-pull rod, actuating the aileron.

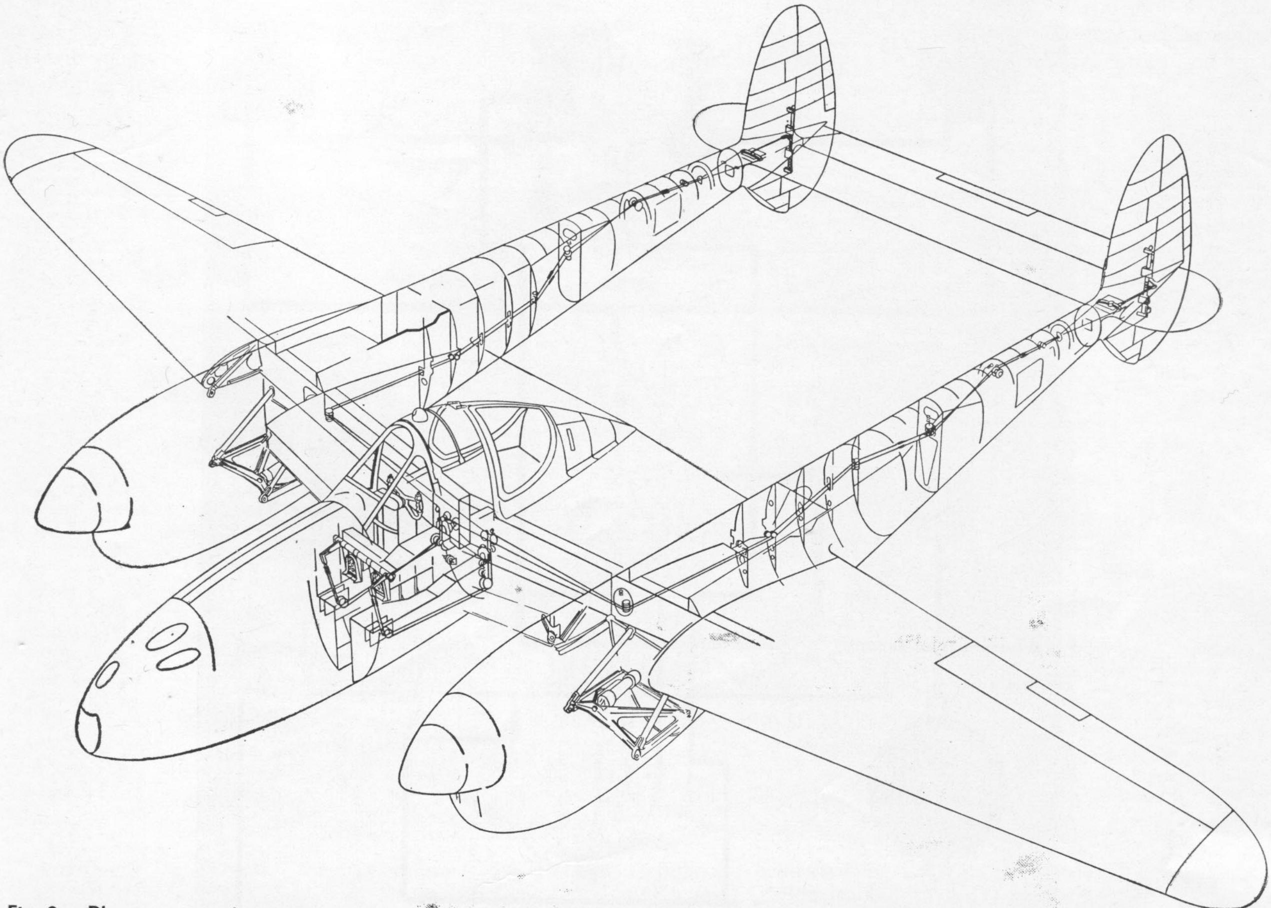


Fig. 3. Phantom view showing continuity of the rudder control cables from the rudder pedals back to the main beam, out to and back through booms, to the rudder hinge brackets and torque tubes attached to the rear spars of the stabilizers. Tabs in flush-riveted rudders are also controlled from the cockpit.

built-up aluminum alloy control column for the elevator on which is mounted a control wheel for the ailerons (2). The control wheel has open upper and lower segments, and the upper corner of each of the two closed segments has one control button on the near side and one trigger-type switch on the far side.

Double, extra-flexible, preformed, tinned, carbon steel control cables $\frac{3}{16}$ in. in diameter extend from the rudder pedals and control column back through the fuselage, diverging outward at the center section main beam to each boom (3).

One set of control cables for both elevator and rudders extends aft through each boom. Antifriction-type bearing pulleys and micarta or fiber guide blocks are used throughout the entire cable system. All control-system bell cranks and masts for actuating the control system are mounted on antifriction bearings and are housed

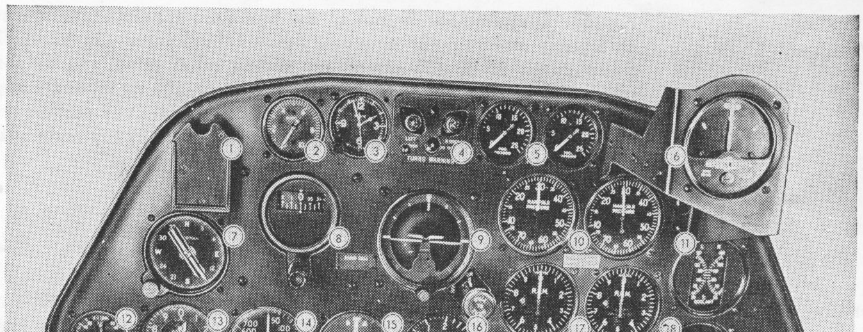


Fig. 4. Lightning instrument panel: (1) compass deviation card holder; (2) vacuum gauge; (3) clock; (4) turbo warning; (5) fuel-pressure gauges; (6) radio compass indicator (optional); (7) remote compass indicator; (8) turn indicator; (9) flight indicator; (10) manifold-pressure gauges; (11) coolant-temperature gauge; (12) fuel-quantity gauge (front); (13) altimeter; (14) air-speed indicator; (15) bank-and-turn indicator; (16) rate-of-climb indicator; (17) tachometers; (18) carburetor air temperature; (19) fuel-quantity gauge (rear); (20) hydraulic-pressure gauge; (21) bank-and-turn regulating valve; (22) landing gear and flap indicator; (23) engine gauges; (24) radio contactor; (25) ammeter.

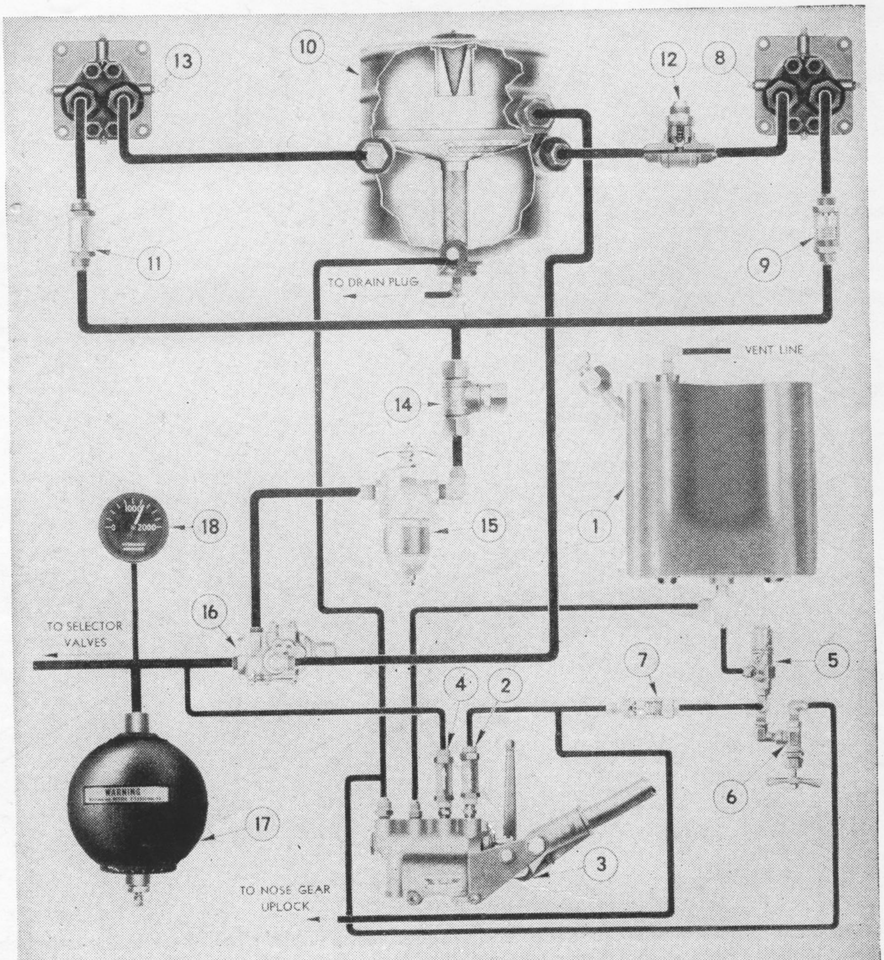


Fig. 5. Diagrammatic layout of the hydraulic system up to the accumulator, showing (1) emergency reservoir; (2) emergency pump check valve; (3) hydraulic hand pump; (4) hand-pump check valve; (5) emergency system relief valve; (6) by-pass valve; (7) emergency return check valve; (8) right-hand engine pump; (9) right-hand pump check valve; (10) main system reservoir; (11) left-hand pump check valve; (12) suction test check valve; (13) left-hand engine pump; (14) pressure test check valve; (15) main system filter; (16) pressure regulator; (17) accumulator; (18) system pressure gauge.

entirely within the aircraft contour. Inspection and service openings with flush-type cover plates are provided throughout.

Automatic electric regulators are connected through a push-pull rod and bell-crank linkage from the throttle control pulley at the fire wall and operate in combination with the throttles.

The hydraulic system (5) of the P-38 operates the landing gear, landing gear doors, wing flaps, coolant radiator exit flaps, and aileron boosters. Pressure is supplied by two engine-driven variable volume pumps and maintains a fluid pressure in the system of 1,350 psi. An auxiliary hand pump with a reserve supply of fluid provides for the operation of all units should the drive system fail.

An emergency hydraulic system, with separate lines and reservoir using the auxiliary hand pump for pressure source, provides a means of extending the landing gears in case the main hydraulic system fails. Fluid capacity of the main system is 10 gal. Aluminum alloy tubing is used throughout the plane, with all tubes grounded by means of bonding clips and fair-leads.

Oil filtering is accomplished at the reservoir in such a way that no unfiltered fluid can reach the system either from the return line or by refilling. The hydraulic system is supercharged for maximum high-altitude efficiency.

The electric system is 24-volt, d-c, single-wire, except for the 115-volt alternating current supplied by the inverter for the remote compass. A 24-volt battery is supplemented by two 100-amp generators to provide power to drive motors and to operate radios, actuating solenoids, instruments, lights, and heaters. Engine starters, oil cooler and intercooler flaps, auxiliary fuel pumps, remote compass inverter, turbo regulator, dive flaps,

and propeller motors are all electrically powered (6).

Electric solenoids control the armament, droppable tanks and bombs, outer wing tank flow, oil dilution valves and coolant flap override mechanism.

Electrically operated instruments include landing gear warning lights; oil-, coolant-, and carburetor air-temperature indicators; fuel-level gauges; remote compass indicator; and tachometers (4).

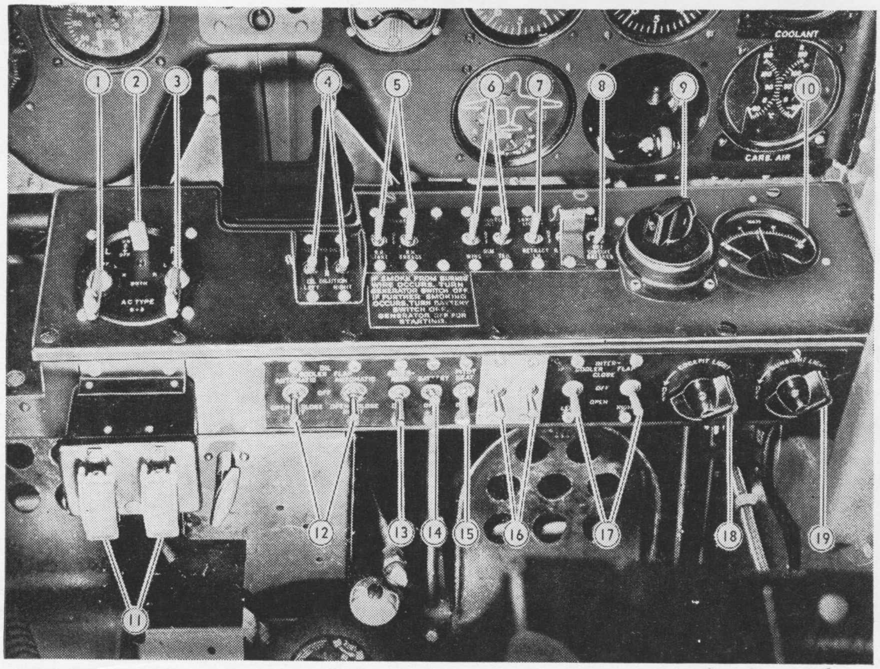


Fig. 6. Main switch box, showing (1) left ignition; (2) master ignition; (3) right ignition; (4) oil dilution; (5) engine starter; (6) position light; (7) left landing light; (8) remote compass switch (circuit breaker); (9) fluorescent cockpit light rheostat; (10) voltmeter; (11) propeller feathering switches; (12) automatic oil cooler flap; (13) generator; (14) battery disconnect; (15) Pitot heater; (16) automatic coolant control override switch; (17) intercooler flap; (18) cockpit light; (19) gun-sight light.

Douglas A-20

Sealed ball-bearing hinges are used for all control surfaces of the A-20. Carbon steel flexible cables with swaged fittings and ball-bearing pulleys connect them to the control wheel and pedals in the pilot's cockpit, the only point of control in the aircraft (1).

The hydraulic system (2) is the "medium-pressure" type, consisting of two engine-driven pumps (either of which can furnish the required pressure, one serving as a stand-by), a hydraulic fluid reservoir, and a pressure accumulator (3). A hand pump furnishes pressure for ground operation when the engines are not being run, and for emergency pressure in the air or in landing.

The hydraulic systems operate the landing gear, wing and cowl flaps, bomb-bay doors, and main landing gear brakes.

Instrument installation on the A-20:

Flight Instruments. Air-speed indicator, altimeter, clock, turn-and-bank indicator, suction gauge, compass, flight indicator, turn indicator, outside-air thermometer, and rate-of-climb indicator.

Engine Instruments. Two each of tachometers, oil-temperature indicators, manifold-pressure gauges, engine-temperature indicators, oil-pressure gauges, fuel-pressure gauges, carburetor-mixture temperature indicators, and a fuel-quantity indicator.

Miscellaneous Instruments. Hydraulic pressure gauge; indicator unit for landing wheels and wing flaps.

Navigation Instruments. Mark 11 drift recorder (rear cockpit, stowed); Mark 11 astro compass (rear cockpit, stowed).

The radio units include one SCR-274 command set; one SCR-535 identification set; one RC-36 interphone system; and one MN-26 radio compass.

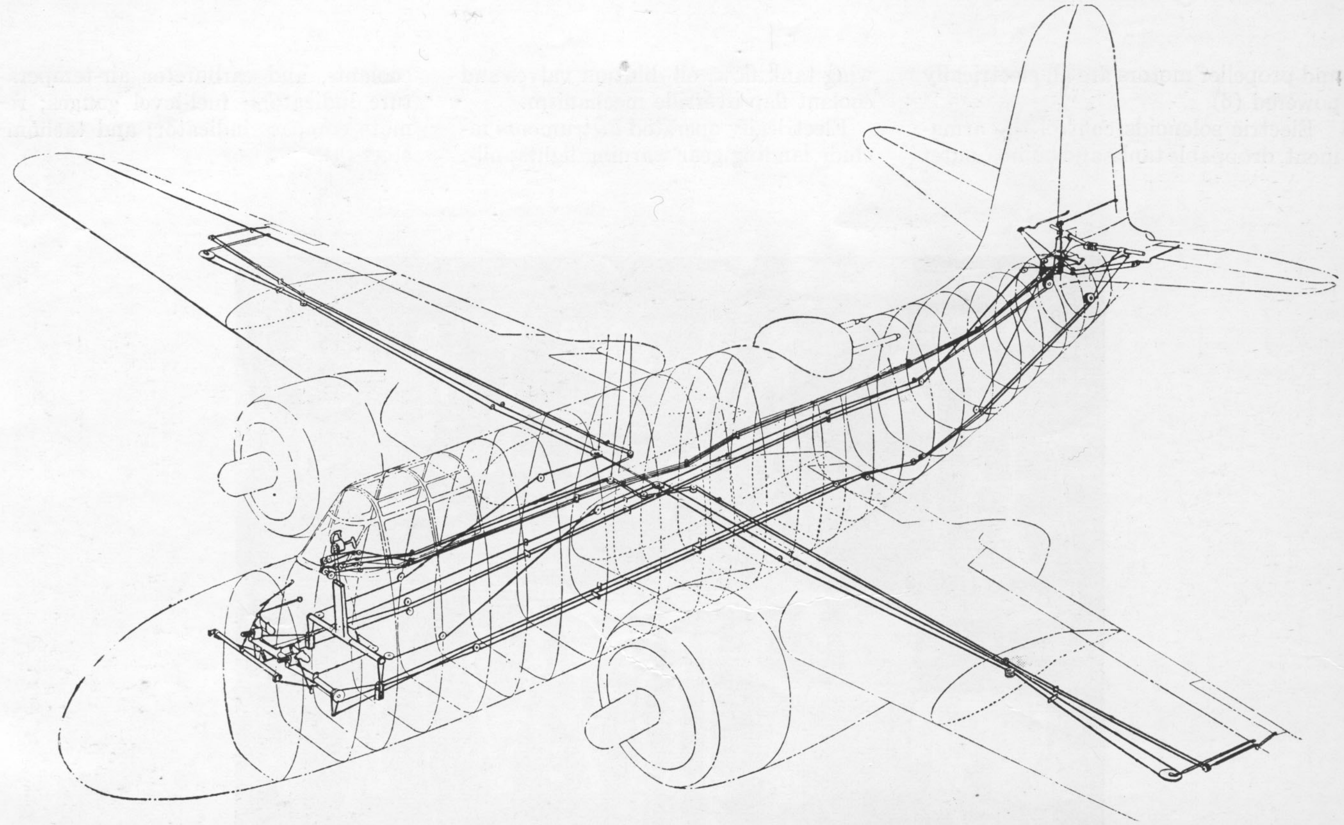


Fig. 1. Flight controls. The rudder and brake are pedal-operated. The ailerons control from the wheel, and the elevators through fore-and-aft motion of the steering column. Tabs are adjusted by hand. Note the universal joint in the elevator shaft. Tension on the cables is taken care of by turnbuckles.

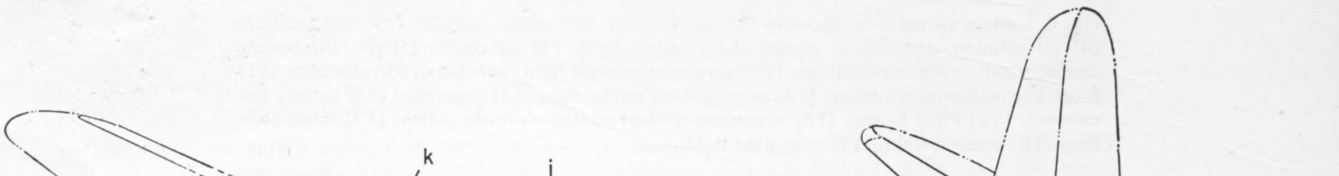


Fig. 2. The hydraulic system is supplied with liquid under pressure by pumps a, a, drawing the supply from reservoir b, through regulating valves in the front bomb bay which keep pressure between 825 and 875 psi. Check valves retain pressure in case of pump failure or leakage. Fluid passes to pressure accumulator c, and thence to selector valves for various systems—landing gear, bomb doors, brakes, wing flaps, and cowl flaps. By-pass operates when pressure exceeds 1,025 psi. The rear wheels are operated by cylinders e and the front wheel by cylinder d. The bomb doors are opened and closed by the large vertical cylinder g in the center of the fuselage. Brakes are controlled by valve h, which admits pressure to the system. Cylinders i actuate the inboard flaps, and j the outboard. The cowl flaps open and close by action of cylinders k,k. Fluid return lines lead back to reservoir b.

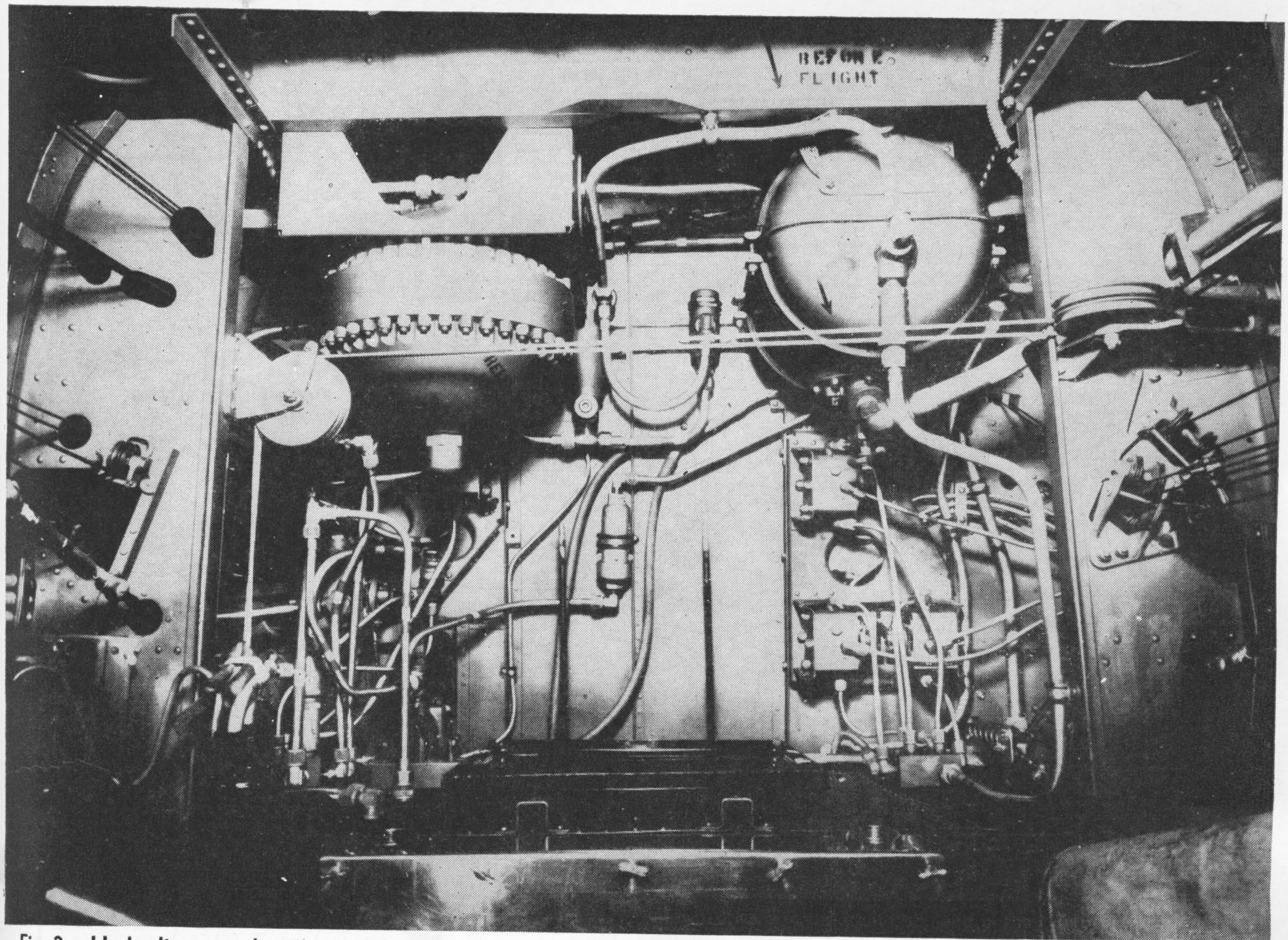


Fig. 3. Hydraulic accumulator (upper left) and reservoir (upper right). A view looking forward to the front bulkhead of the bomb bay.

PART 3. AIRCRAFT HAVING FOUR OR MORE ENGINES

Lockheed Constellation (049, 149)

The Constellation is controlled by conventional aileron, elevator, and rudder control surfaces, operated by dual controls, each consisting of a control wheel and column and rudder pedals.

Hydraulic booster units are built into the cable control system in such a manner that each takes its proportion of the load required to move or sustain the surfaces against air loads (2). Each booster assembly includes an actuating cylinder which converts the hydraulic pressure to motion, and a four-way control valve which regulates the direction of motion. Any movement of the control cable opens the control valve. When the cable movement is discontinued, the control valve is closed by the actuating cylinder through a parallelogram linkage follow-up. The follow-up linkage is limited in its travel so that the cables actuate the surfaces without assistance of the hydraulic pressure when the hydraulic pressure is shut off.

A by-pass valve integral with the actuating cylinder is linked to a cable-operated shutoff valve. When the shutoff valve is closed, the by-pass valve is open and allows free movement of the piston within the actuating cylinder.

A filter is installed upstream of each booster control valve to prevent foreign matter from interfering with proper functioning of the booster mechanism.

The air flow to the engine master control is controlled by two doors which are operated by electrical actuators (1). Control switches for the actuators are on the flight engineer's control stand. One door is located in the leading edge of the engine upper cowl panel and is used to select either rammed air through the upper scoop or alternate air from a duct in the L.E. of the engine cowling. The other door is located immediately forward of the master control and is used to select either alternate air from the upper scoop or preheat air from a duct around the exhaust manifold. The preheat door may be set in any intermediate position to permit varying amounts of alternate and preheat air to enter the master control.

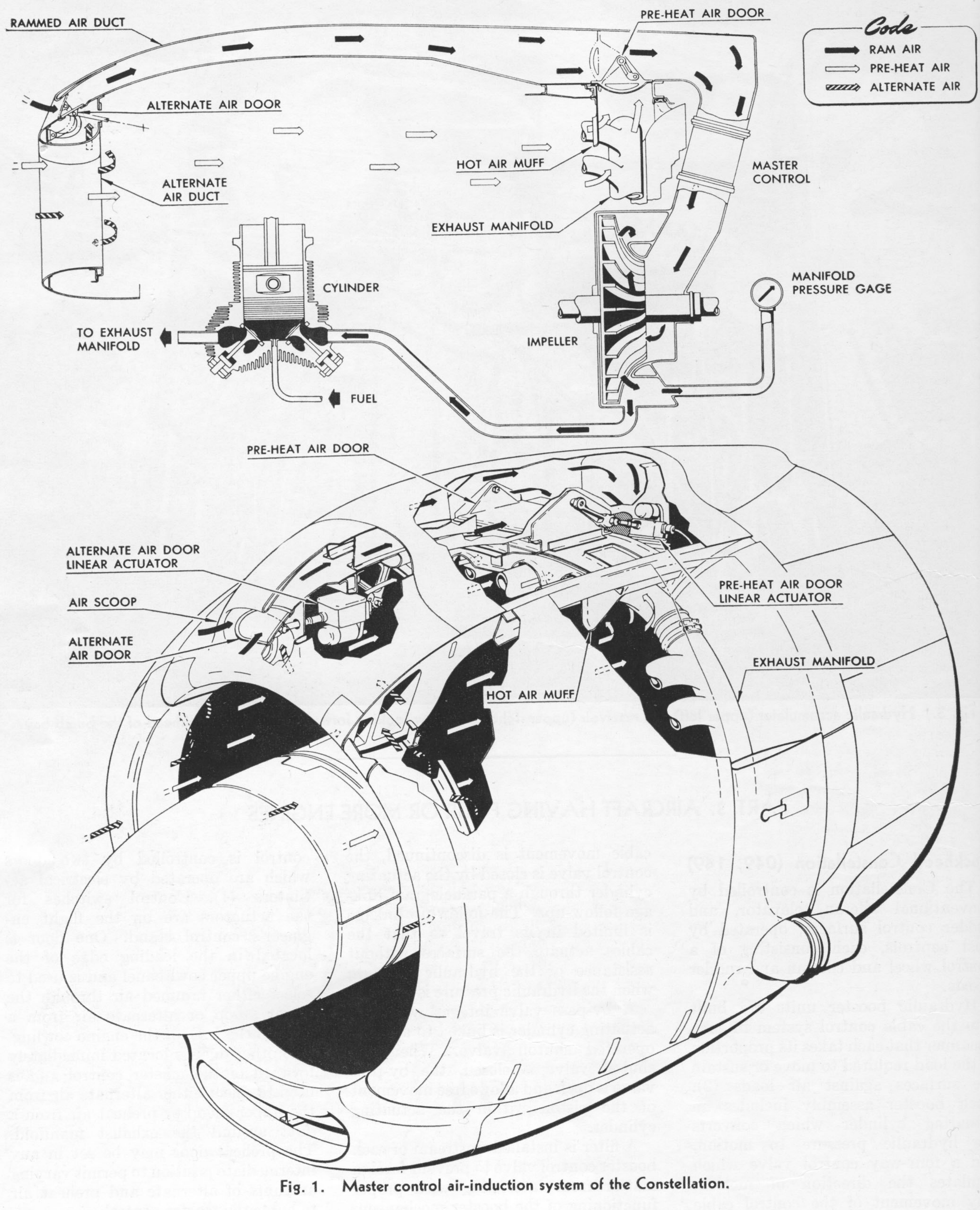


Fig. 1. Master control air-induction system of the Constellation.

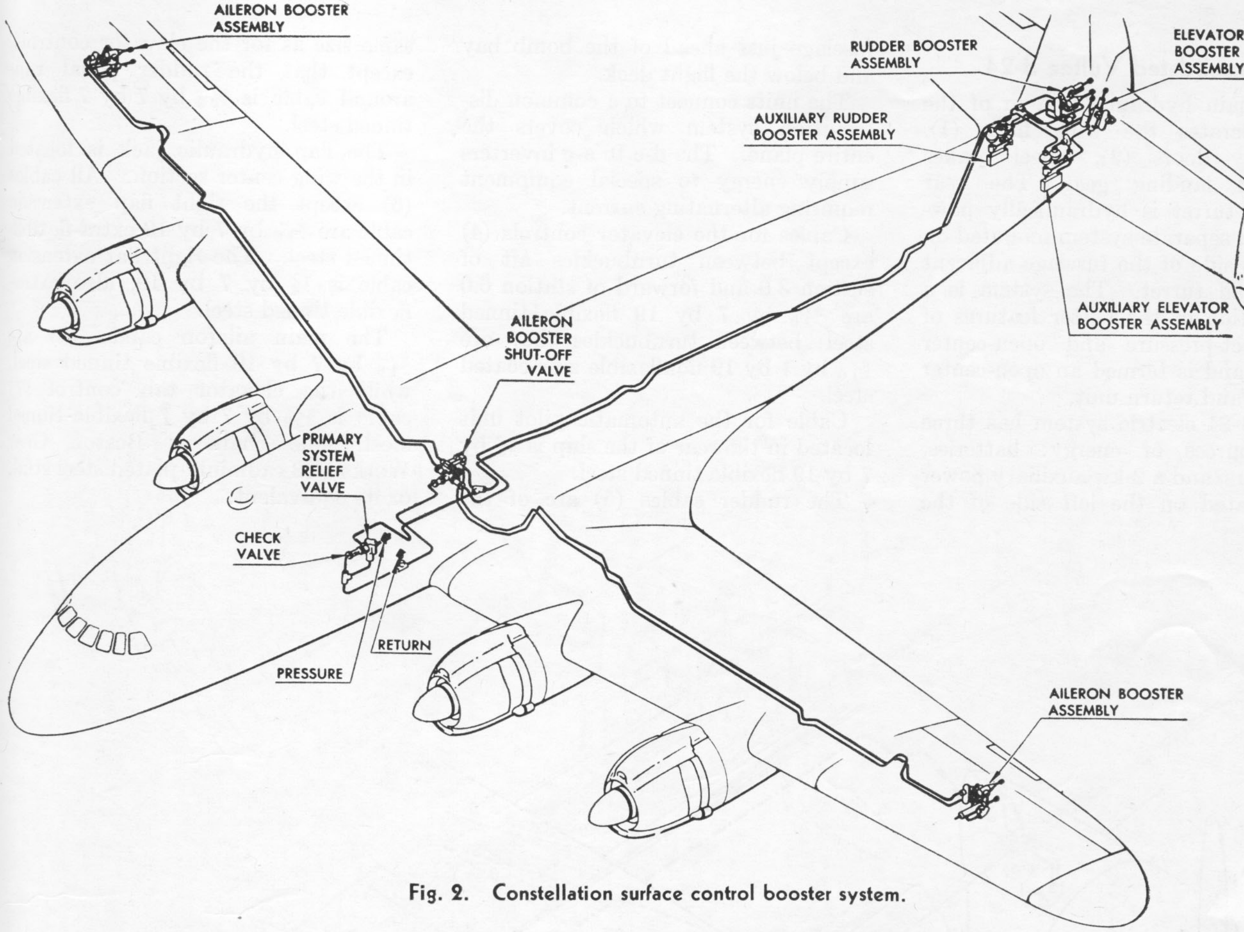


Fig. 2. Constellation surface control booster system.

Boeing B-29

In the Boeing B-29 Superfortress, the flap actuator motor (1) is located on the aft face of the rear spar. The 24-volt, 31-lb 4-oz motor develops 1,500 lb-in. torque on torque tubes through gear reduction.

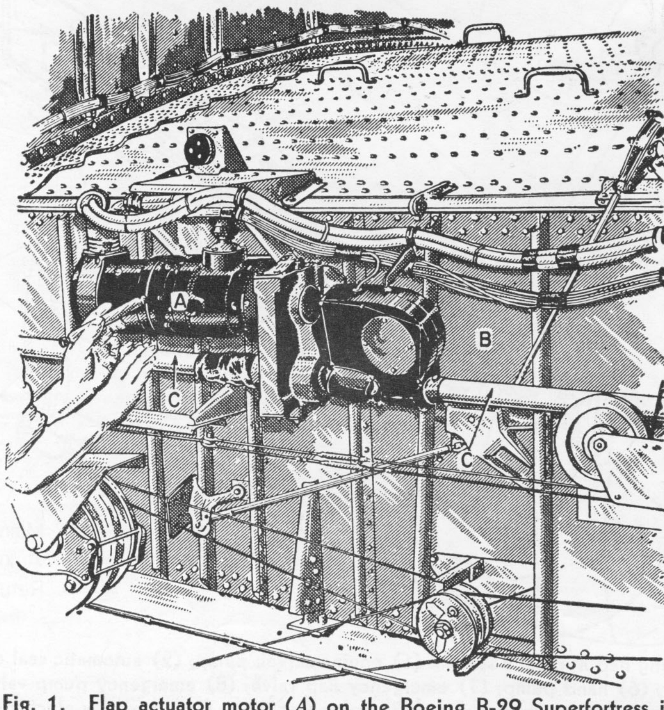


Fig. 1. Flap actuator motor (*A*) on the Boeing B-29 Superfortress is located on the aft face of rears spar (*B*). Through internal gear reduction, the 24-volt 31-lb 4-oz motor develops 1,500 lb-in. torque on torque tubes (*C*).

Consolidated Vultee B-24

The main hydraulic system of the B-24 operates the wing flaps (1), bomb-bay doors (2), wheel brakes (3), and landing gear. The rear gunner's turret is hydraulically powered by a separate system mounted on the right side of the fuselage adjacent to the tail turret. The system is a combination of the better features of the direct-pressure and open-center systems and is termed an open-center pressure and return unit.

The B-24 electric system has three main sources of energy: batteries, generators, and a 2-kw auxiliary power unit located on the left side of the fuselage just ahead of the bomb bay and below the flight deck.

The units connect to a common distribution system which covers the entire plane. The d-c to a-c inverters supply energy to special equipment requiring alternating current.

Cables for the elevator controls (4) except between turnbuckles aft of station 3.0 and forward of station 6.0 are $\frac{3}{16}$ by 7 by 19 flexible tinned steel; between turnbuckles they are $\frac{3}{16}$ by 1 by 19 nonflexible zinc-coated steel.

Cable for the automatic pilot unit located in the rear of the ship is $\frac{1}{8}$ by 7 by 19 flexible tinned steel.

The rudder cables (5) are of the same size as for the elevator controls, except that the rudder pedal run-around cable is $\frac{3}{32}$ by 7 by 7 flexible tinned steel.

The flap hydraulic jack is located in the wing center section. All cables (6) except the right flap extension cable are $\frac{3}{16}$ by 7 by 19 extra-flexible tinned steel. The right flat extension cable is $\frac{1}{4}$ by 7 by 19, also extra-flexible tinned steel.

The main aileron cables (8) are $\frac{3}{16}$ by 7 by 19 flexible tinned steel, while the elevator tab control (7) cable is $\frac{3}{32}$ by 7 by 7 flexible tinned steel. The chain is Boston Gear Works 5B2 cadmium-plated steel stud, or its equivalent.

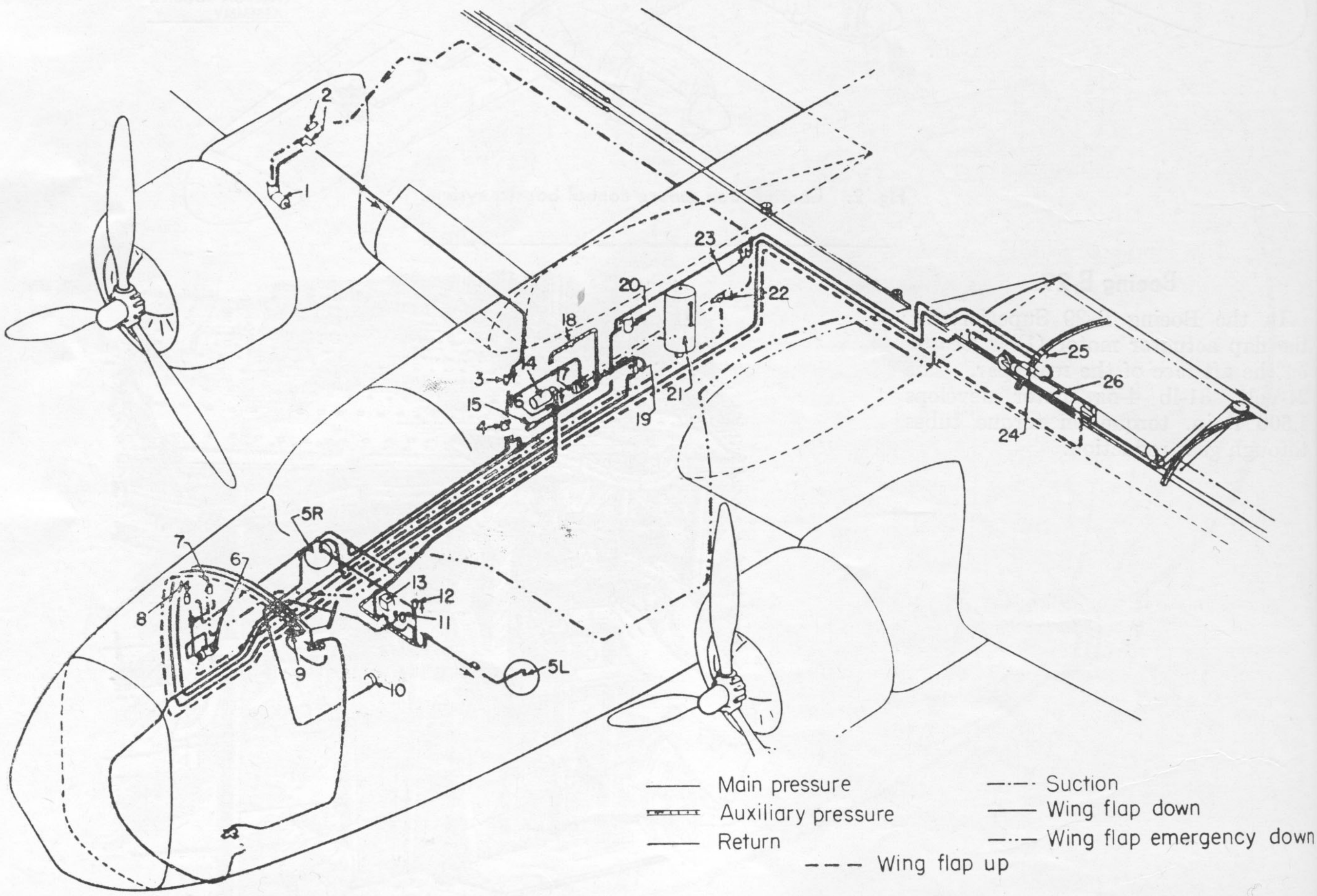


Fig. 1. Wing flap hydraulic system: (1) engine-driven pump; (2) automatic seal coupling; (3) engine pump check valve; (4) relief valve; (5) accumulator; (6) hand pump; (7) emergency flap valve; (8) emergency pump valve; (9) flap selector valve; (10) pressure gauge; (11) check valve; (12) accumulator check valve; (13) unloading valve; (14) auxiliary electric pump; (15) auxiliary pump relief valve; (16) auxiliary pump check valve; (17) test stand valve; (18) emergency crossover valve; (19) pressure switch; (20) filter; (21) reservoir; (22) emergency reservoir valve; (23) suction line check valve; (24) shuttle valve; (25) flap relief valve; (26) flap cylinder.

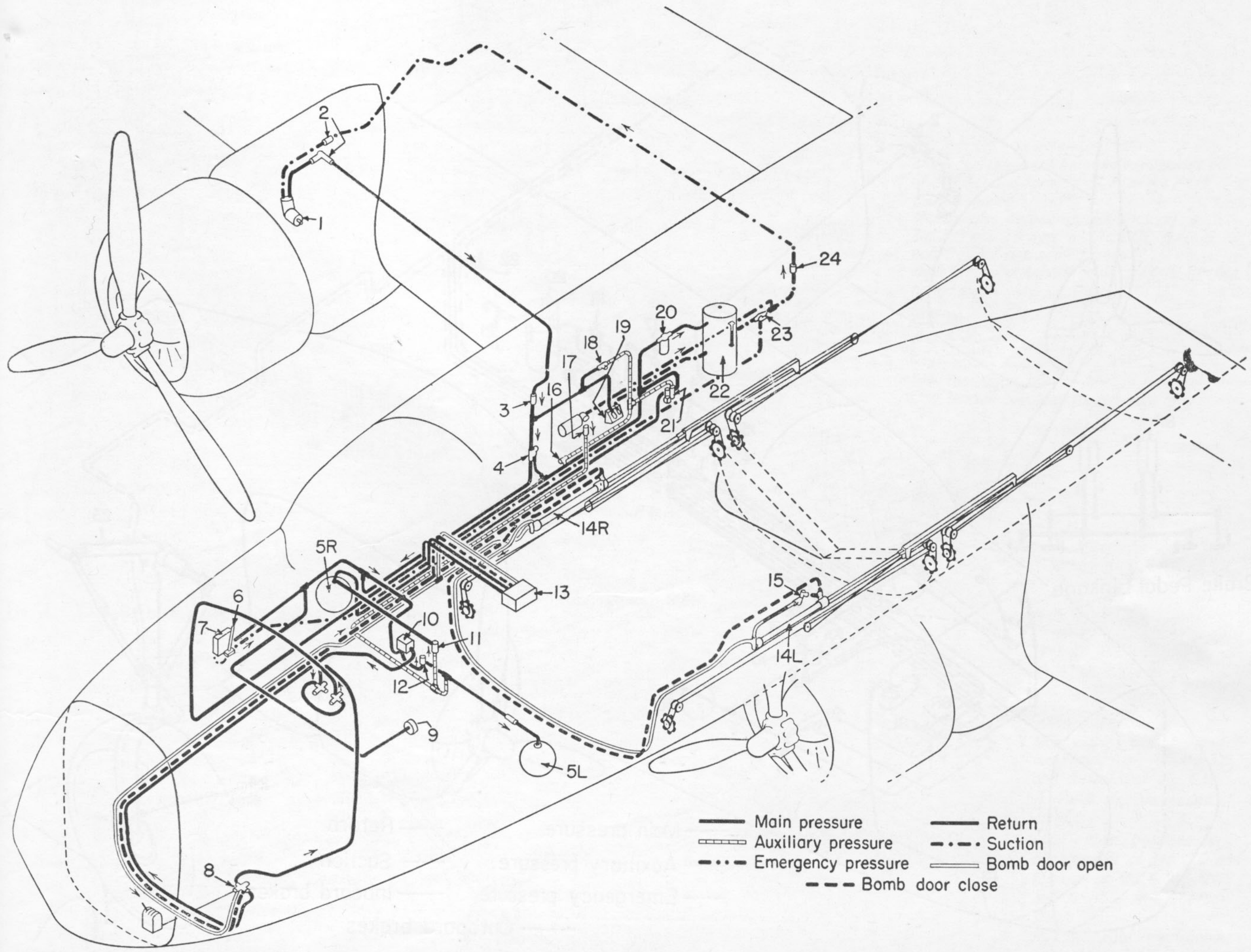


Fig. 2. **Bomb-door hydraulic system: (1) engine-driven pump; (2) automatic seal coupling; (3) engine pump check valve; (4) relief valve; (5) accumulator; (6) hand pump; (7) emergency flap valves; (8) bomb-door selector valve; (9) pressure gauge; (10) unloading valve; (11) accumulator check valve; (12) check valve; (13) bomb-door emergency and utility control valve; (14) bomb-door cylinder; (15) bomb-door relief valve; (16) auxiliary pump relief valve; (17) auxiliary pump check valve; (18) emergency crossover valve; (19) test stand valve; (20) filter; (21) pressure switch; (22) reservoir; (23) emergency reservoir valve; (24) suction line check valve.**

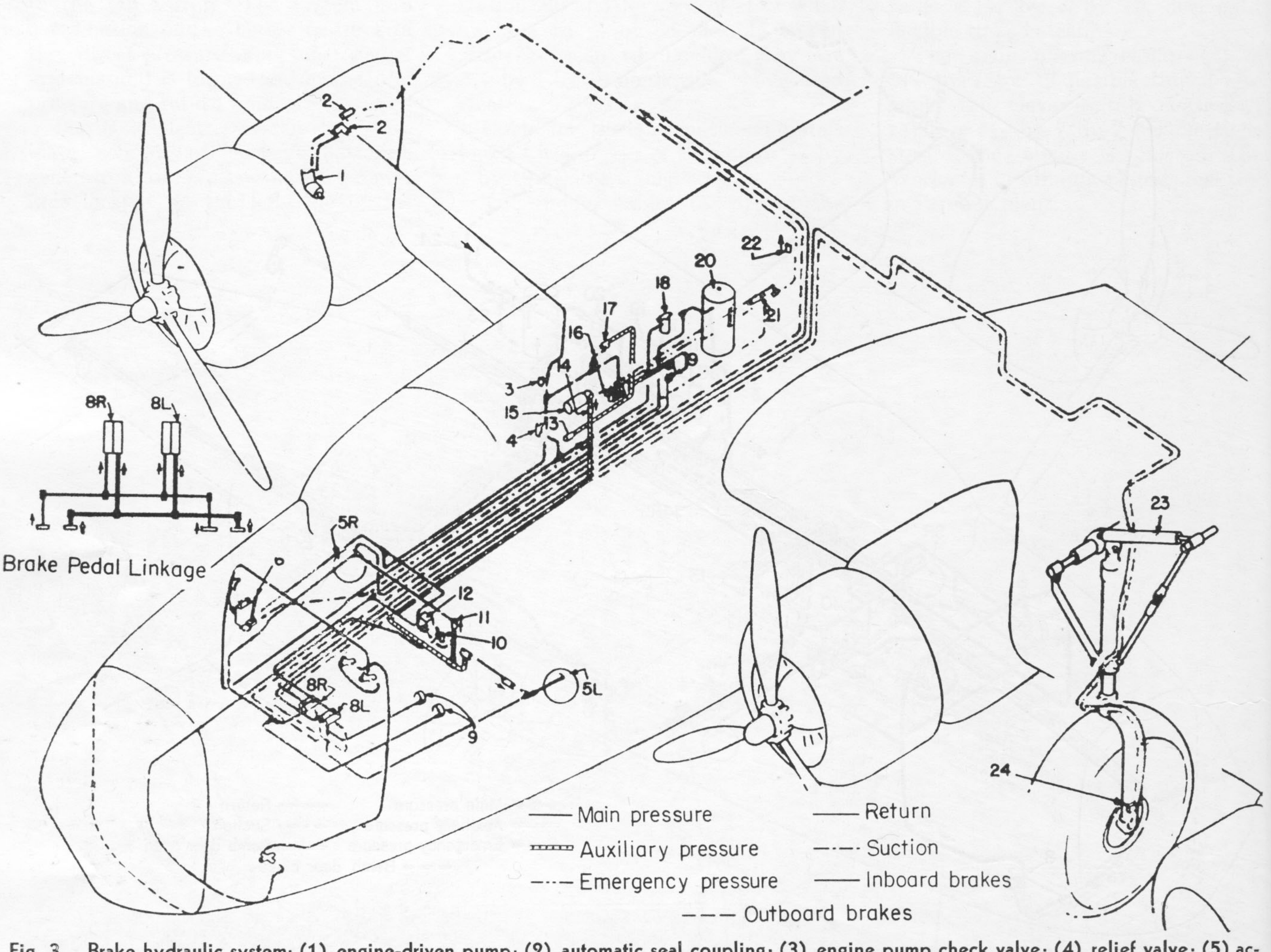
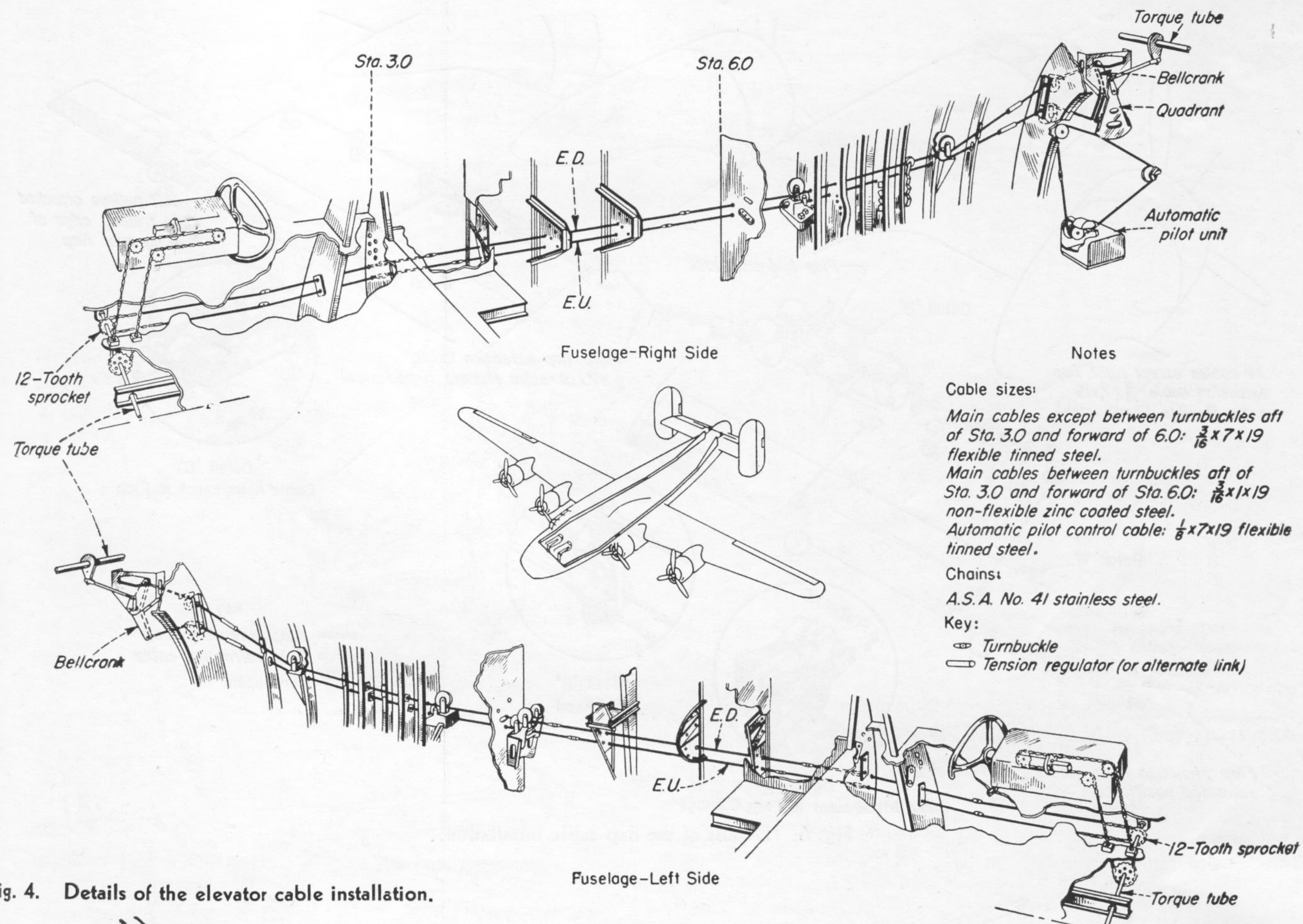


Fig. 3. Brake hydraulic system: (1) engine-driven pump; (2) automatic seal coupling; (3) engine pump check valve; (4) relief valve; (5) accumulator; (6) hand pump; (7) flap valves; (8) brake control valve; (9) pressure gauge; (10) check valve; (11) accumulator check valve; (12) unloading valves; (13) auxiliary pump relief valve; (14) auxiliary pump check valve; (15) auxiliary electric pump; (16) test stand valves; (17) emergency crossover valve; (18) filter; (19) pressure switch; (20) reservoir; (21) emergency reservoir valve; (22) suction line check valve; (23) landing gear cylinder; (24) brake bleeder valve.



Notes

Cable sizes:

Main cables except between turnbuckles aft of Sta. 3.0 and forward of 6.0: $\frac{3}{16}$x7x19 flexible tinned steel.
Main cables between turnbuckles aft of Sta. 3.0 and forward of Sta. 6.0: $\frac{3}{16}$x1x19 non-flexible zinc coated steel.
Automatic pilot control cable: $\frac{1}{8}$x7x19 flexible tinned steel.

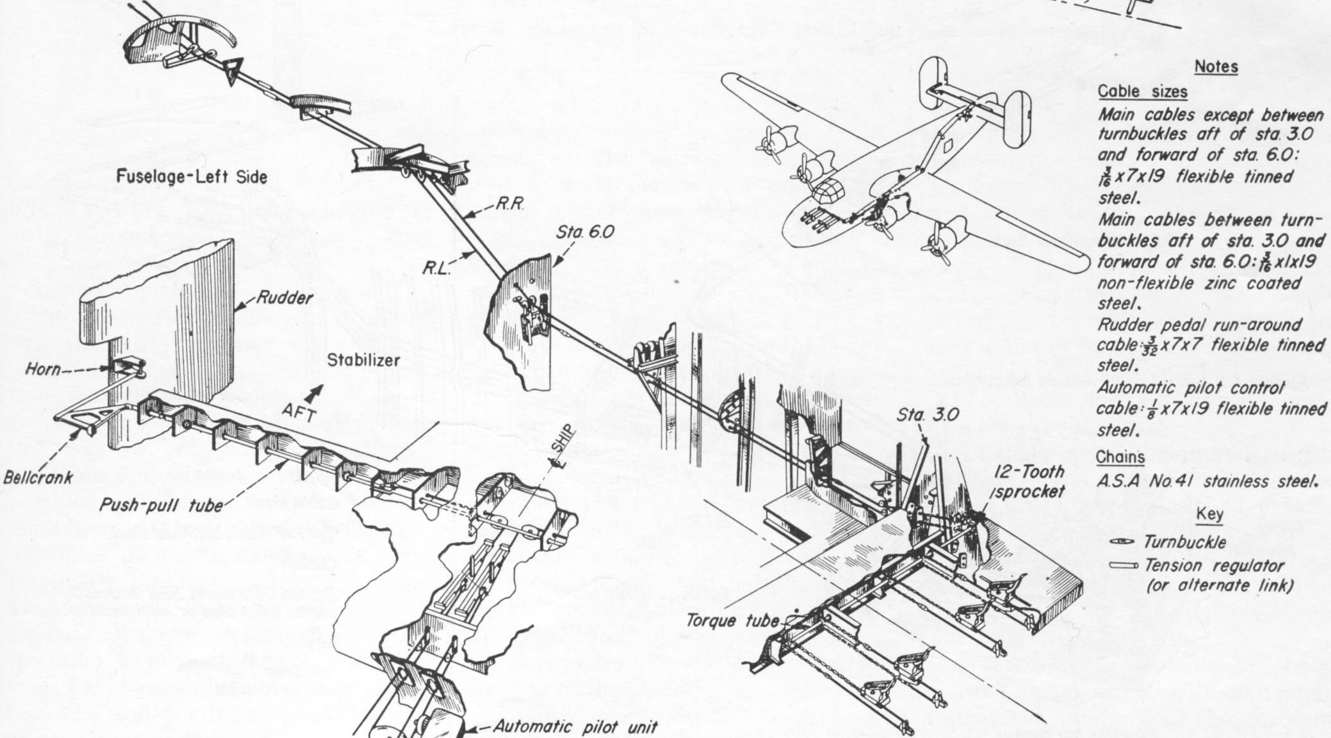
Chains:

A.S.A. No. 41 stainless steel.

Key:

Turnbuckle
Tension regulator (or alternate link)

Fig. 4. Details of the elevator cable installation.



Notes

Cable sizes

Main cables except between turnbuckles aft of sta. 3.0 and forward of sta. 6.0: $\frac{3}{16}$x7x19 flexible tinned steel.
Main cables between turnbuckles aft of sta. 3.0 and forward of sta. 6.0: $\frac{3}{16}$x1x19 non-flexible zinc coated steel.
Rudder pedal run-around cable: $\frac{3}{32}$x7x7 flexible tinned steel.
Automatic pilot control cable: $\frac{1}{8}$x7x19 flexible tinned steel.

Chains

A.S.A No. 41 stainless steel.

Key

Turnbuckle
Tension regulator (or alternate link)

Fig. 5. Details of the rudder cable installation.

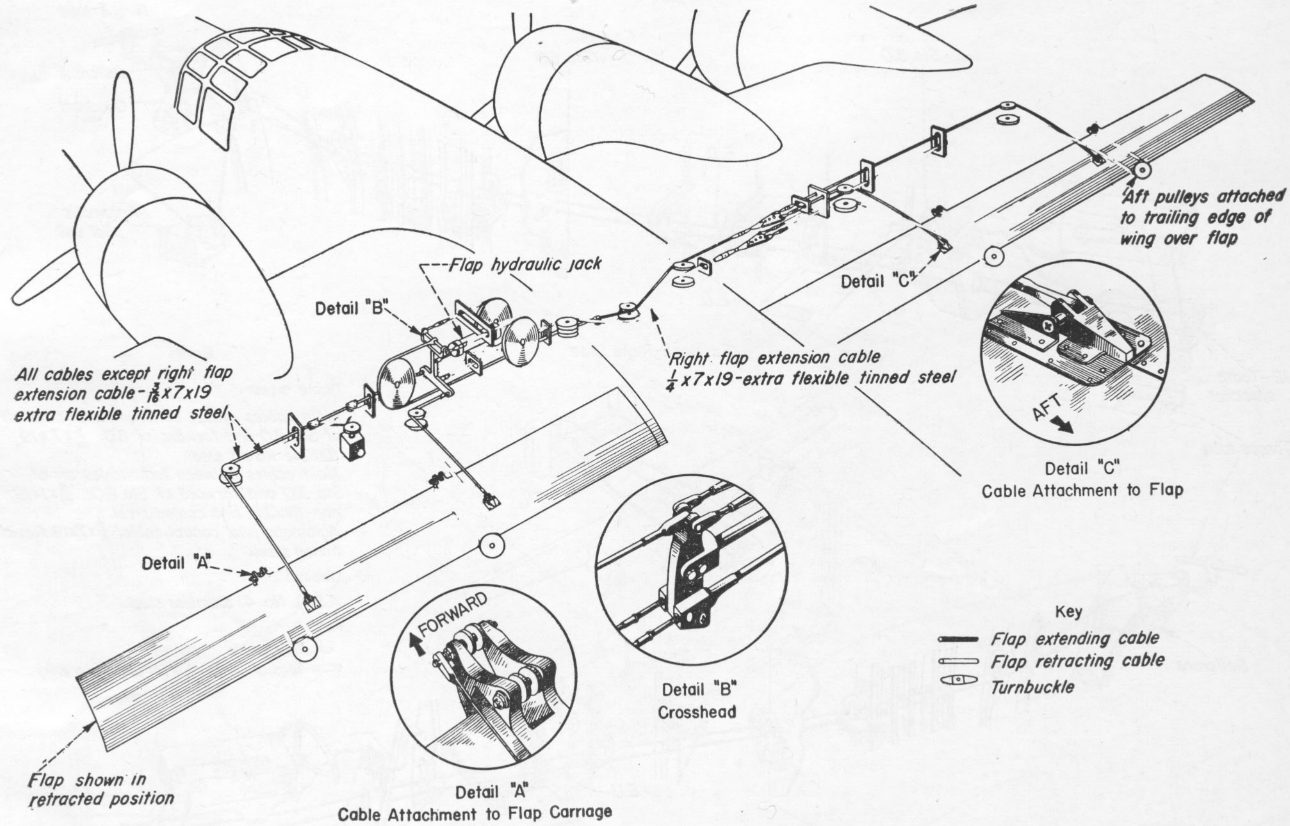


Fig. 6. Details of the flap cable installation.

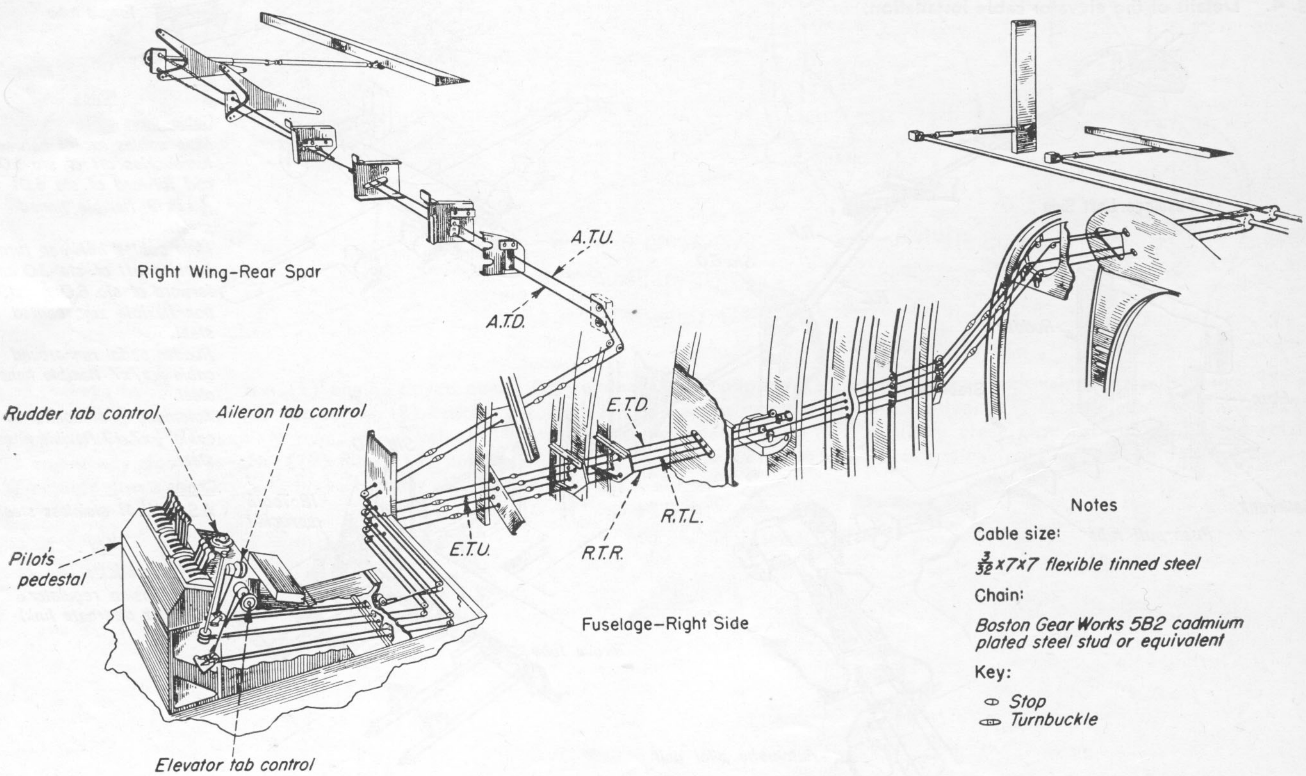


Fig. 7. Details of the tab cable installation.

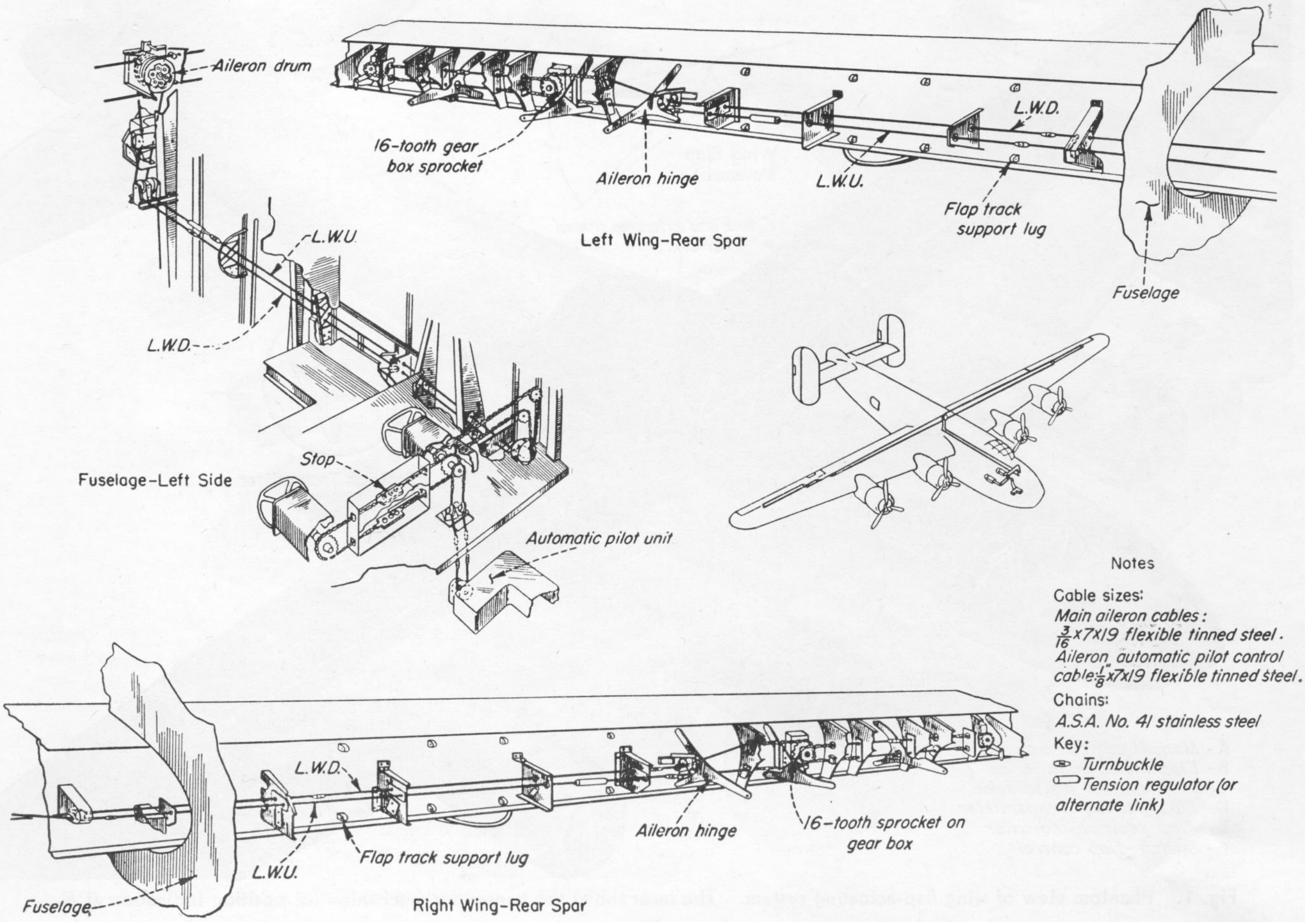


Fig. 8. Details of the aileron cable installation.

Boeing B-17

One of the first aircraft to "put the breeze to work" to relieve controls of loads through the use of tabs, the B-17 is also one of the first to actuate retractable gear and other parts by means of electric motors as well as by manual drive shafts.

This electrical installation has proved to be an outstanding member of that group of original innovations for which the plane has become famous. Combat damage, it was reasoned, would be less likely to put entire units out of commission if they were electrically controlled by means of dispersed and practically duplicate wiring systems. Thousands of instances of partial combat damage which failed to prevent operation have confirmed the soundness of that reasoning. Landing gear, flaps (1), and bomb-bay doors are all electrically operated.

Manual control systems, likewise, are rather unique in that all those connected with surface controls connect to and operate over quadrants, which makes them free-moving and easy to handle. The routing of cables is direct, with a minimum of pulleys and sharp angles in cable courses (2, 3, 4, 5).

A fuse panel on the rear bulkhead of the cockpit contains 45 of the 77 fuses in the bomber. In addition, the landing gear indicating relay is mounted on a bracket on the panel.

A small auxiliary panel contains five fuses and a control relay for the carburetor air-filter motors, indicator lights, and switch; and four fuses for the bombardier's and pilot's windshields. Still another panel, beside the lower turret, contains eleven fuses for electrical and radio equipment in the rear of the plane.

Landing gear motors are all controlled by switches at the pilot's station. The motors are mounted at the upper end of the retracting mechanism in the inboard nacelles, receive unfused power through two solenoids, and actuate the gear through a planetary 40:1 reduction gear, clutch assembly, and solenoid engaging mechanism.

The retracting motor for the tail wheel is mounted above the wheel and actuates it through a clutch and reduction gear and solenoid engaging jaw. Means for mechanical control also are provided (6).

A single motor, mounted on the left side of the catwalk at the forward end of the bay, actuates the bomb-bay doors. Solenoids are mounted on an adjacent bulkhead. The doors may be opened with a handcrank inserted through a hole in the step at the forward end of the catwalk.

Other electrical circuits are bomb control, flight control, deicer and pump, instrument, interior and exterior lighting, propeller feathering, starter, and warning signals. All are installed

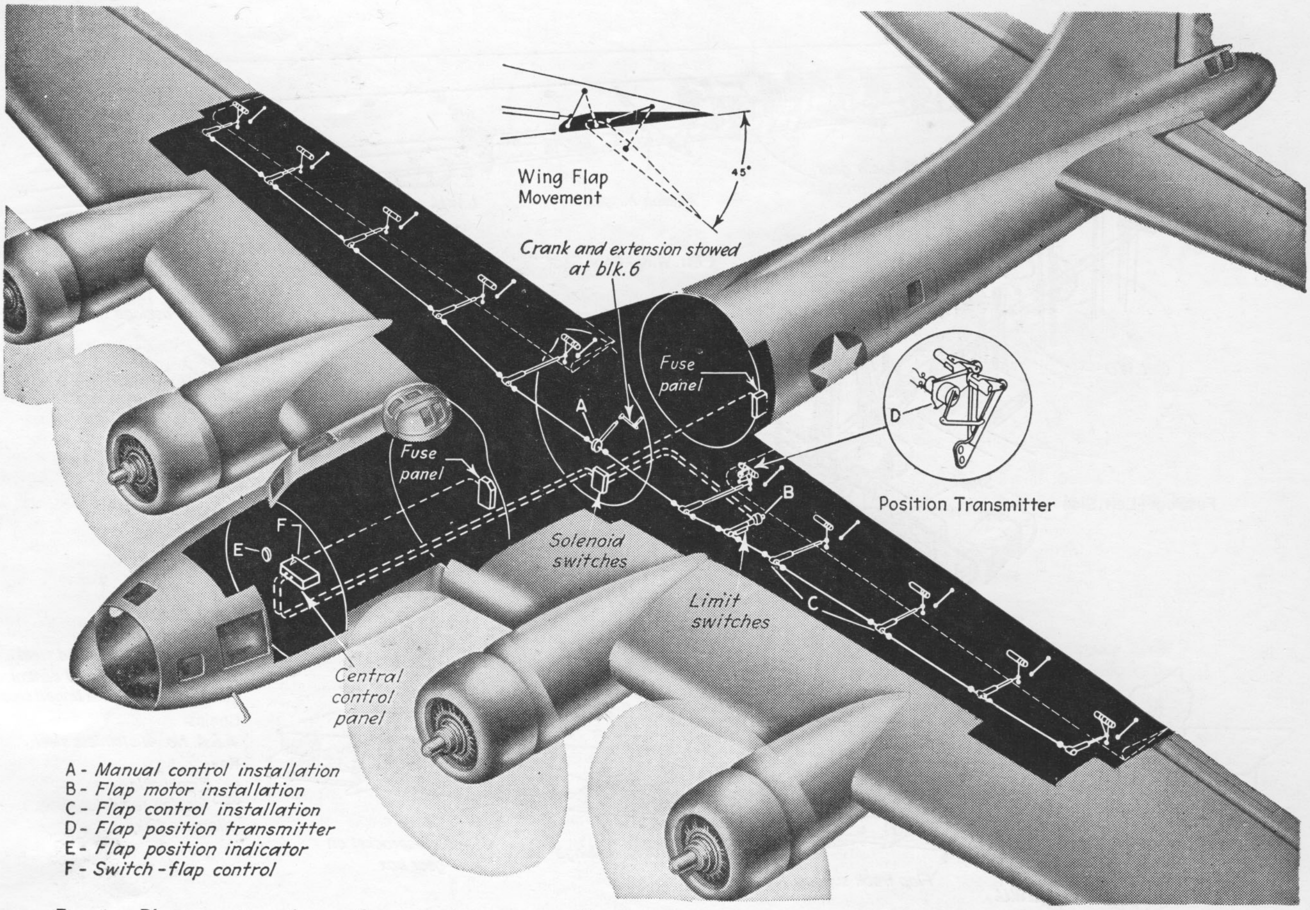


Fig. 1. Phantom view of wing flap-actuating system. The inset shows the transmitter mechanism for position indication at *E*.

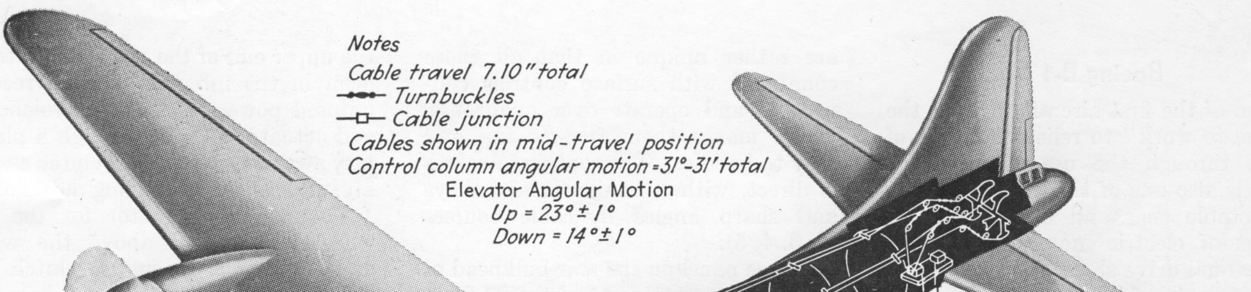


Fig. 2. Phantom view of the elevator control system.

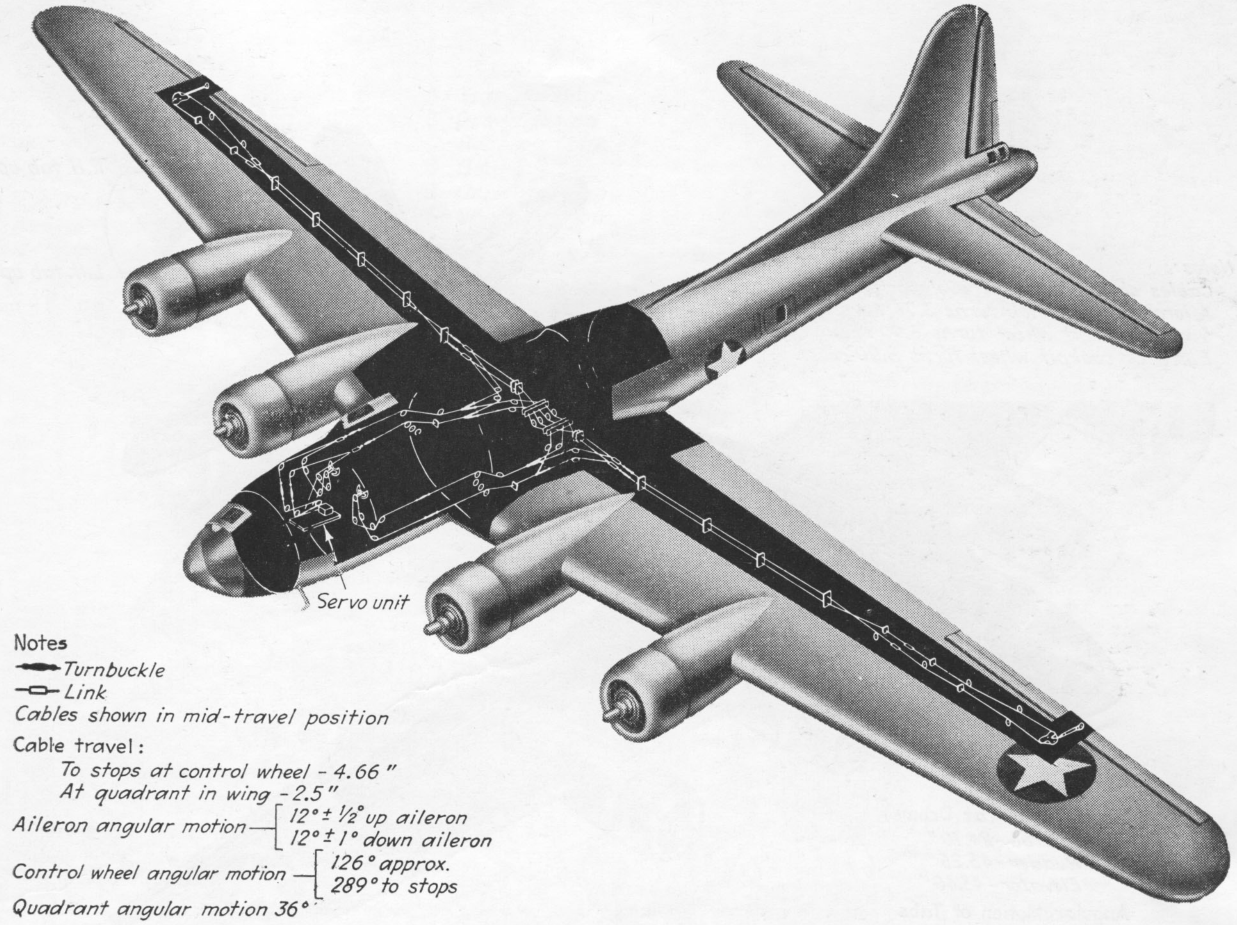


Fig. 3. Phantom view depicting the aileron control system.

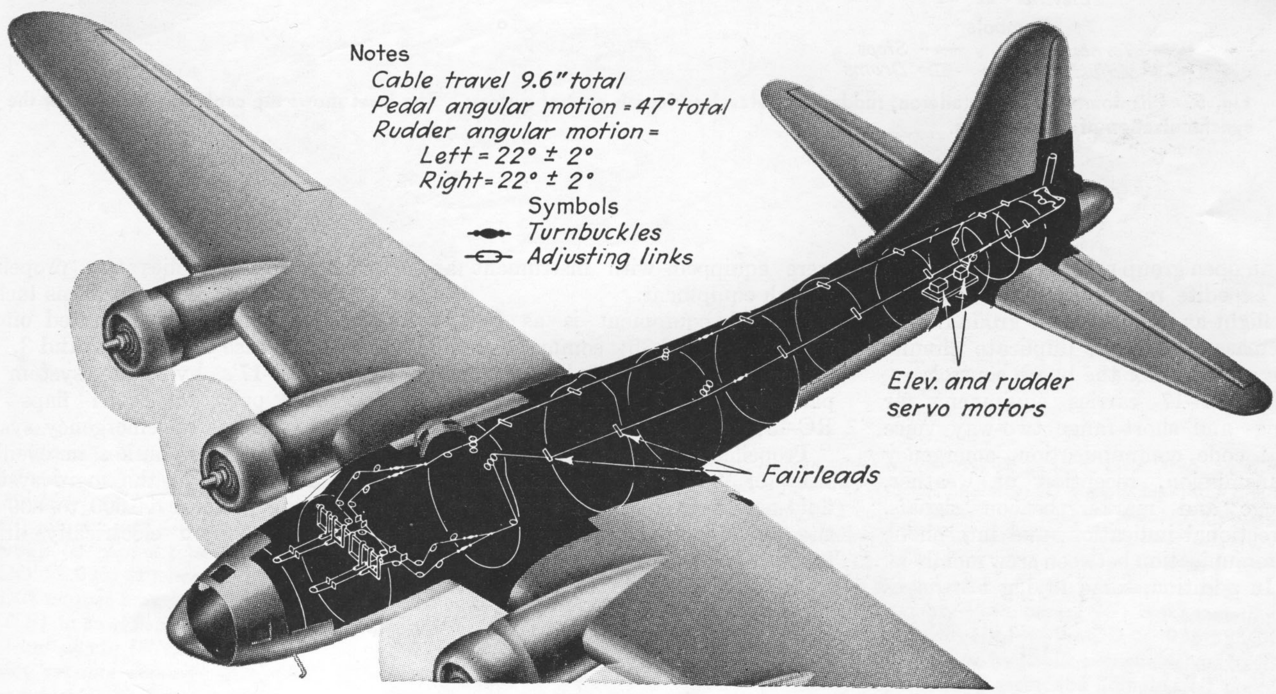


Fig. 4. Phantom view of the rudder control system. The quadrant at the extreme right is attached to a torque tube.

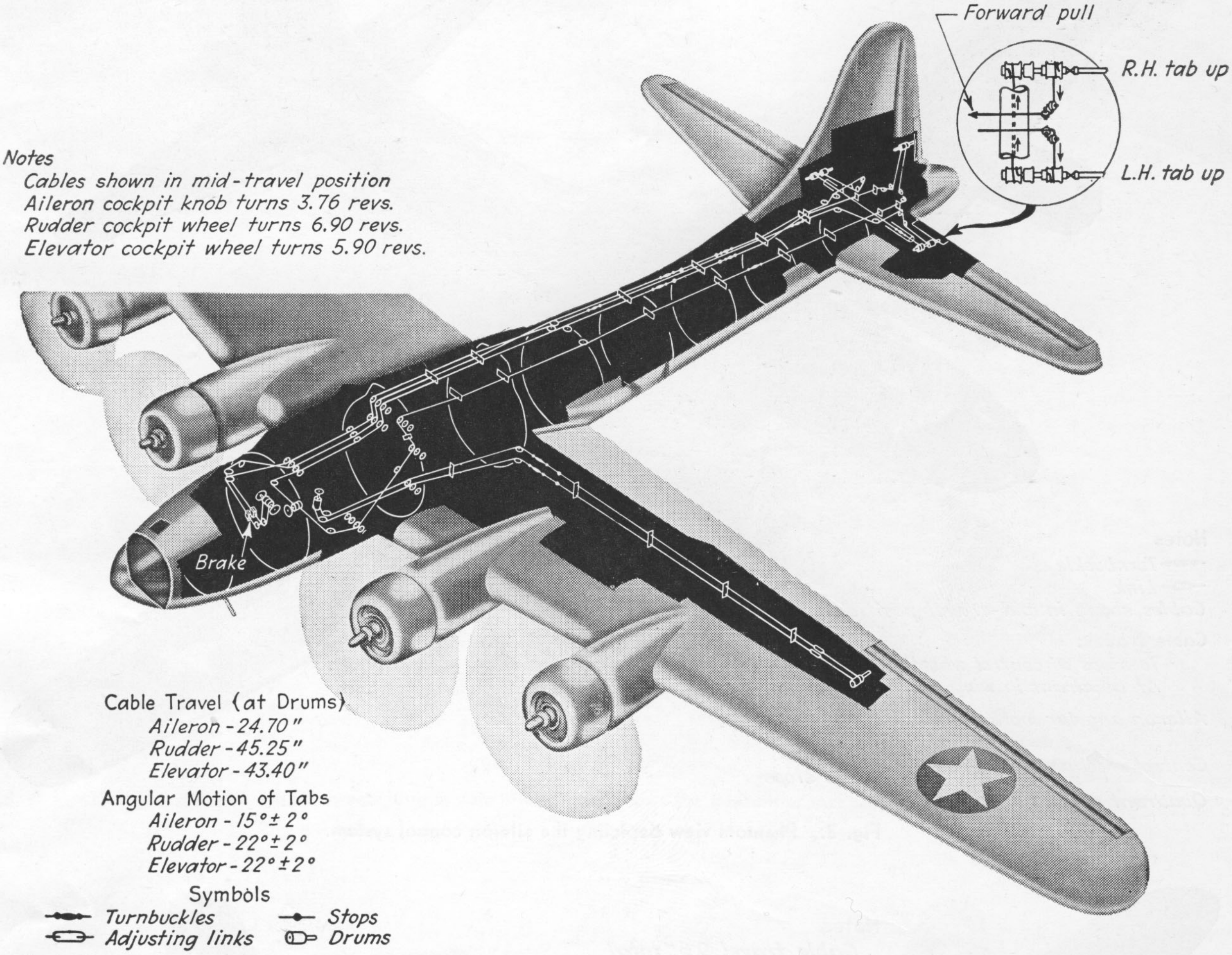


Fig. 5. Phantom view of the aileron, rudder, and elevator trim tab control systems. The inset shows the cable arrangement for the synchronization of elevator tabs.

in an open group rather than in conduit to expedite repair of gunfire damage, in flight as well as on the ground. To increase reliability, duplicate circuits are provided for the bomb controls.

The B-17 carries equipment for long- and short-range two-way voice and code communication, emergency transmission, reception of weather, range and marker beacon signals, directional indication, and interphone communication between crew members.

In addition, some Flying Fortresses were equipped with instrument approach equipment.

Normal equipment is as follows: interphone, RC-36; command radio; liaison radio, SCR-287-A; radio compass, SCR-269-G; marker beacon, RC-43; and emergency radio, SCR-578.

Propeller anti-icing equipment consists of two electric motor-driven fluid-metering pumps located beneath the radio compartment floor at the forward end of the camera pit. Fluid is obtained from a 20-gal tank, and each pump supplies two propellers.

Vacuum and deicer systems include two vacuum pumps mounted on the accessory case of engines 2 and 3.

The B-17's hydraulic system (7) operates only the cowl flaps and brakes. It has an emergency system for operating the brakes in event of pressure failure in the main system. Operating pressure is 600 to 800 psi, developed by an electrically driven pump.

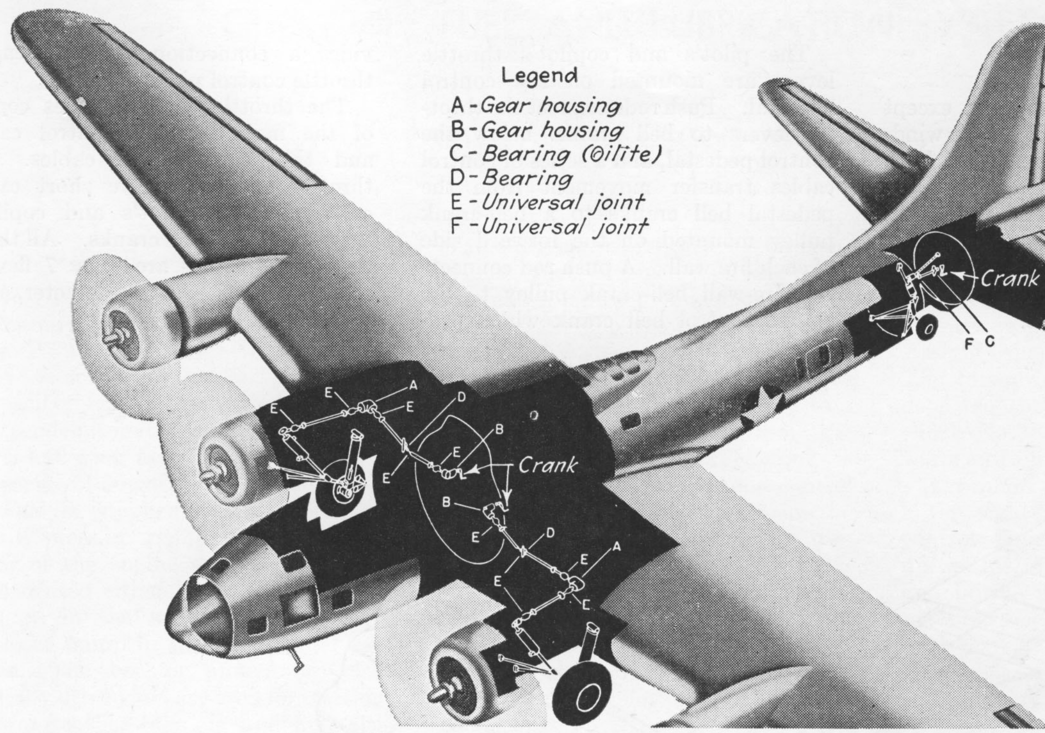


Fig. 6. Phantom view of the landing and tail gear hand retracting systems.

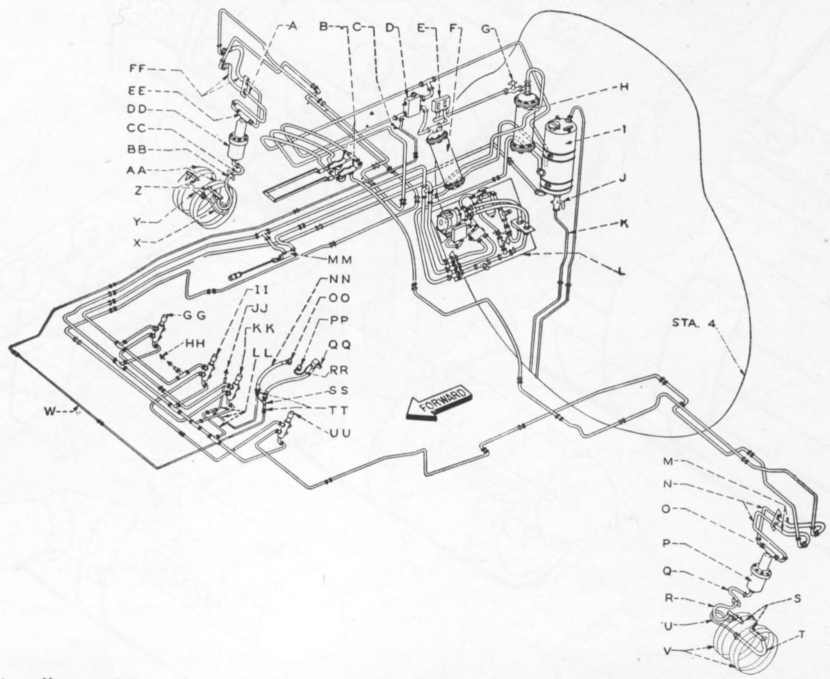


Fig. 7. **Hydraulic system installation: (*A*) copper tube ½ in. OD × .35; (*B*) emergency brake metering valves; (*C*) ⅜ in. OD × .035, 52SO; (*D*) relief valve; (*E*) selective check valve; (*F*) emergency accumulator; (*G*) manual shutoff valve; (*H*) accumulator; (*I*) supply tank; (*J*) drain cock; (*K*) ⅜ in. OD × .035, 52SO; (*L*) hydraulic panel; (*M*) hose assembly ½-in. tube; (*N*) copper tube ½ in. OD × .035; (*O*) shuttle valve; (*P*) return boost valve; (*Q*) copper tube ½ in. OD × .035; (*R*) hose assembly ½-in. tube; (*S*) inlet connection; (*T*) hose assembly ½-in. tube; (*U*) copper tube ½ in. OD × .035; (*V*) dual duplex brake expander tubes; (*W*) ⅜ in. OD × .035 52SO; (*X*) copper tube ½ in. OD × .035; (*Y*) hose assembly, ½-in. tube; (*Z*) inlet connection; (*AA*) dual duplex brake expander tubes; (*BB*) hose assembly ½-in. tube; (*CC*) copper tube ½ in. OD × .035; (*DD*) return boost valve; (*EE*) shuttle valve; (*FF*) hose assembly ½-in. tube; (*GG*) brake metering valve; (*HH*) to cowl flap valve; (*II*) brake metering valve; (*JJ*) to cowl flap valve; (*KK*) brake metering valve; (*LL*) ⅜ in. OD × .035 52SO; (*MM*) hand pump; (*NN*) hose assembly ¼ in. ID tube; (*OO*) main hydraulic-pressure valve; (*PP*) emergency hydraulic-pressure valve; (*QQ*) emergency pressure warning switch; (*RR*) ¼ in. OD × .035 52SO; (*SS*) ¼ in. OD × .032 or .035 SO; (*TT*) restriction fitting; (*UU*) brake metering valve.**

Canadair North Star

All flight controls are dual except rudder tab control wheel in the windshield V which is in reach of both pilots. Movable flight control surfaces are operated from the flight compartment through two-way cable systems. Automatic pilot servo units are attached to the aileron, elevator, and rudder cable systems.

The pilot's and copilot's throttle levers are mounted on the control pedestal. Push rods connect the throttle levers to bell cranks below the control pedestal, and a series of control cables transfer movement from the pedestal bell cranks to a bell-crank pulley mounted on the forward side of each fire wall. A push rod connects the fire-wall bell-crank pulley to the engine control bell crank which provides a connection for the engine throttle control pickup.

The throttle control cables consist of the main throttle control cables and the throttle bus cables. The throttle bus cables are short cables connecting the pilot's and copilot's throttle control bell cranks. All throttle control cables are 7 by 7 flexible steel cables, $\frac{3}{32}$ in. in diameter, with swaged end fittings (1).

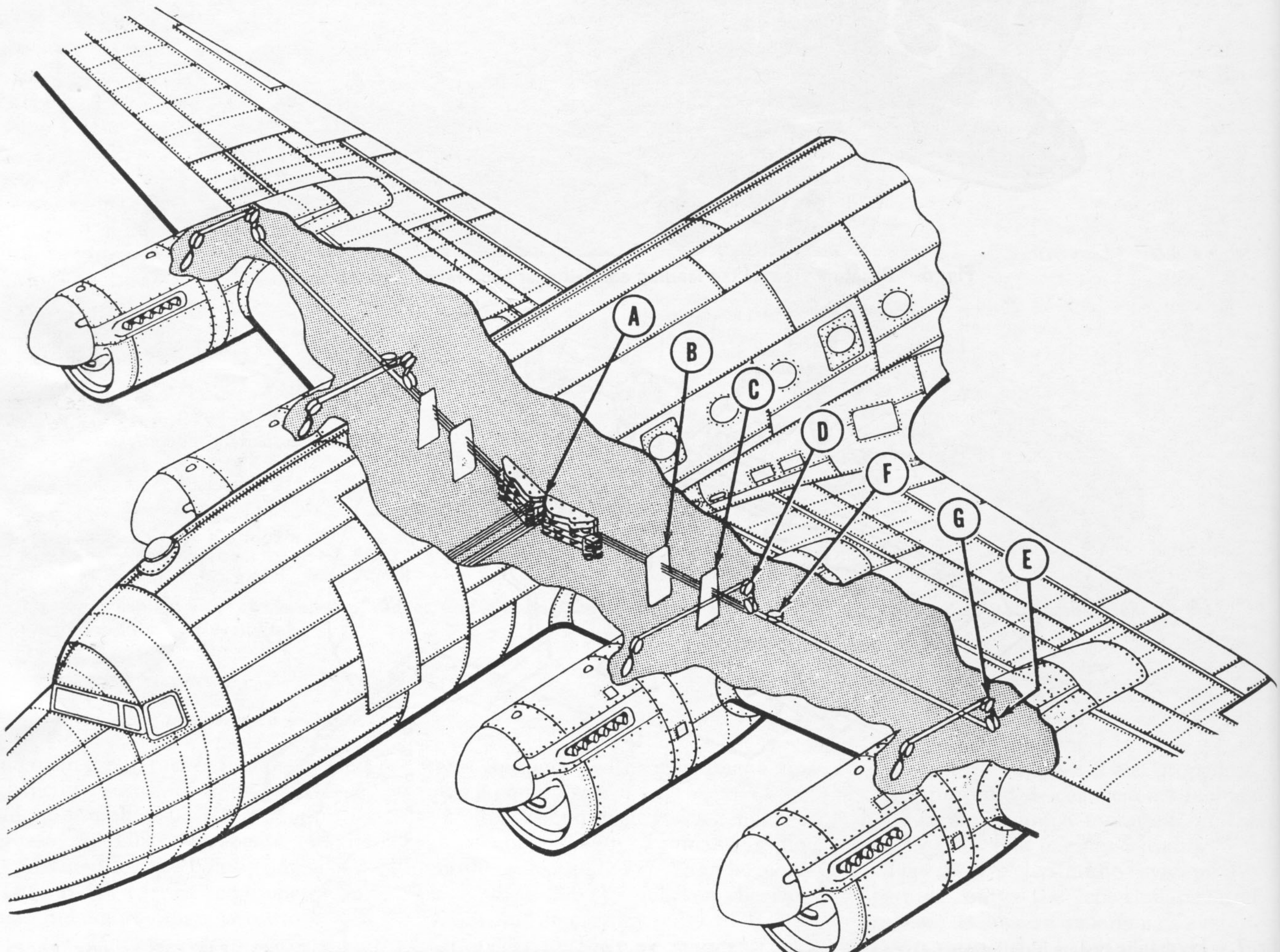


Fig. 1. Throttle control system of the North Star: (*A*) front spar pulley bracket; (*B*) cable fair-leads; (*C*) cable fair-leads; (*D*) inboard nacelle engine control bracket; (*E*) front spar throttle pulley bracket; (*F*) front spar control pulley bracket; (*G*) left outboard nacelle engine control bracket.

Chapter VII. FUEL AND LUBRICATION SYSTEMS

PART 1. SINGLE-ENGINE AIRCRAFT

Bell P-39 Airacobra

In addition to two 6-gal tanks built integrally into the outer wing panels, the P-39 has a droppable auxiliary fuel tank of either 75- or 150-gal capacity, carried in the bomb rack suspended from the wing center section. The left wing tank includes a reserve capacity of 20 gal.

Fuel is supplied to the carburetor by a pressure pump, located in the rear of the engine accessory housing, augmented either by two booster fuel pumps in the wing, or by a single booster pump in the wing center section. The booster pumps are electrically driven and are used for starting, warm-weather take-off, and high-altitude flying to prevent vapor lock.

Between the booster pump and the engine-driven fuel pump are a Lunkenheimer fuel strainer, an air-vapor eliminator, and an air-vapor control valve (1).* The last two are installed to provide a steady flow of fuel when the fuel selector valve is actuated to switch fuel intake from an empty to a full tank. A vent line from the carburetor to the left-wing tank is routed through the air-vapor control valve which prevents vapor in the left-wing tank from backing up into the carburetor.

A fuel-pressure warning switch, connected to the carburetor and carburetor air-intake balance line, is provided along with a light indicator to warn the pilot of fuel-pressure conditions.

* The numbers in parentheses refer to the illustrations.

The carburetor air intake system is comprised of a ramming air scoop, located behind the aft cabin on the aircraft vertical center line, in a straight duct into the carburetor. The forward face of the duct has a door controlled from the cockpit, which closes off cold air and admits warm air from the engine compartment.

A primer pump is installed at the lower right-hand side of the radio control panel. It is hand-operated, draws fuel from the booster pump, and injects it into the engine intake manifold system.

Each fuel tank consists of six leak-proof bags. The left wing tank is equipped with two finger-type fuel strainers, one providing for normal fuel consumption, and the other for reserve fuel consumption. The right-

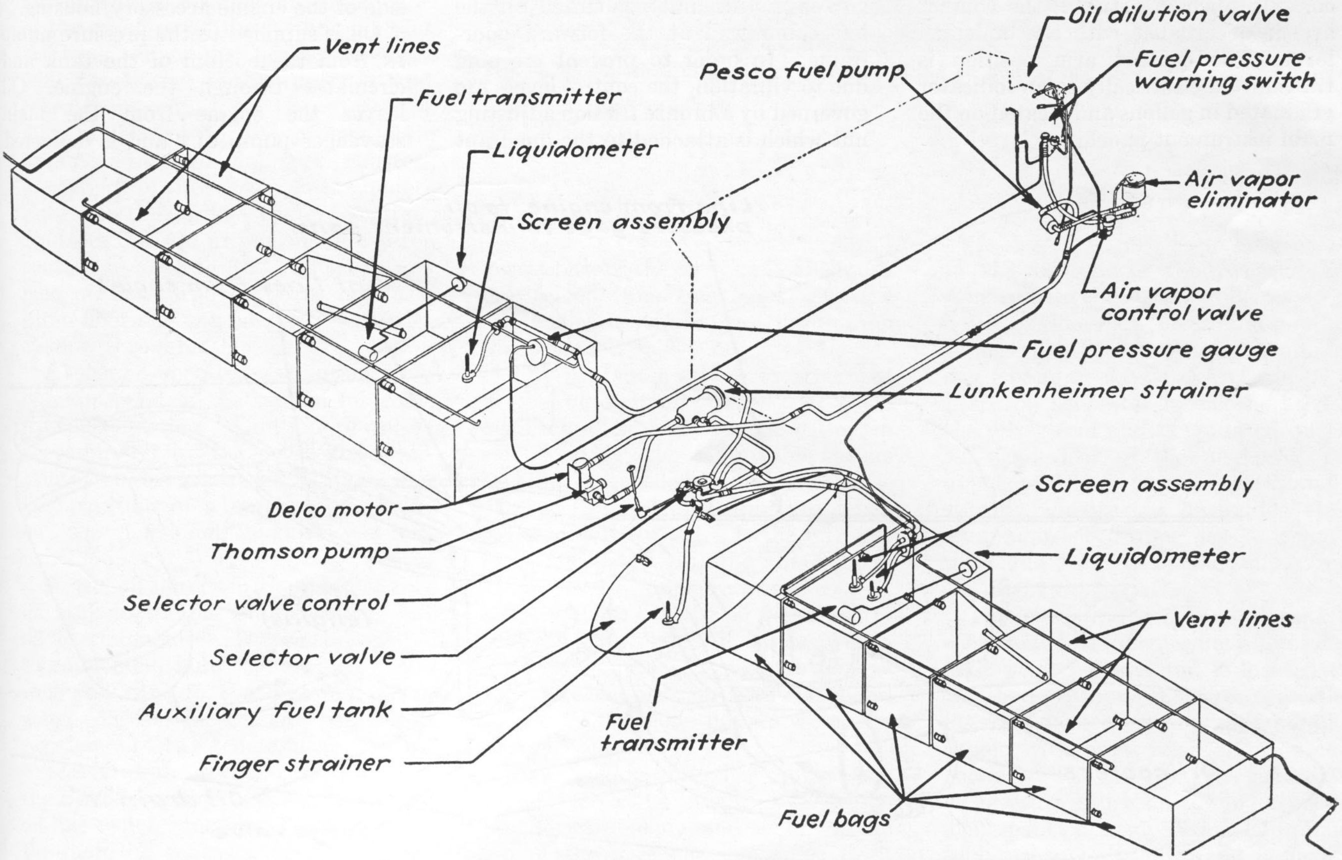


Fig. 1. Schematic diagram of the fuel system of a Bell P-39.

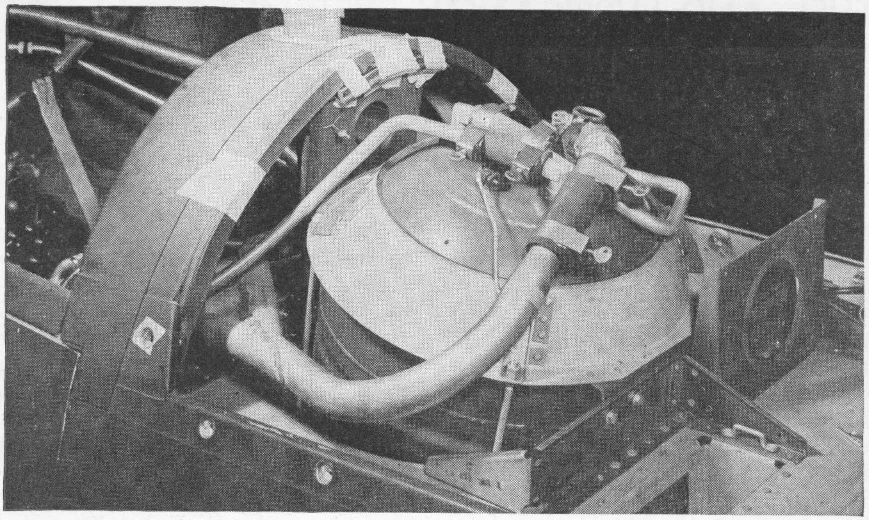


Fig. 2. The engine oil tank is mounted in the aft fuselage structure just behind the engine compartment.

bolt and may be tightened or loosened to permit easy sliding of stiff levers or to allow tightened action of loose levers.

The throttle control lever is located most outboard on the quadrant and governs speed and manifold pressure. The lever knob is equipped with a spring-loaded push button which operates the throat microphone and allows the pilot to operate the radio transmitter without removing his hand from the throttle.

The mixture control which is incorporated with the injection-type carburetor has four main control settings: full rich, automatic rich, automatic lean, and idle cutoff, in the order mentioned. The carburetor mixture can be adjusted by motion of the lever between automatic rich and automatic lean by "click and feel."

Automatic altitude mixture control also is maintained for any fixed position of the control lever between automatic rich and automatic lean.

Engine lubricating oil is circulated by a main pressure pump having a built-in check valve, and a scavenger pump located at the lower right-hand side of the engine accessory housing.

Oil is supplied to the pressure pump IN from the bottom of the tank and circulates through the engine. Oil leaves the engine from the main scavenger pump OUT and is delivered

hand tank includes only one fuel strainer providing for consumption of the entire tank capacity.

Each tank is provided with a liquidometer unit with a resistance strip and movable contact arm, at the end of which is installed a pivoting cork float which actuates the contact arm in accordance with the tank fuel level. The contact arm position is transmitted electrically to an indicator graduated in gallons and located on the main instrument panel.

Electrical connections are installed in shielded conduits between each tank unit and the instrument panel indicator.

Engine throttle and carburetor mixture control levers are assembled into a single unit (propeller pitch control also is in this unit), mounted on the left cabin wall at the forward doorframe. In order to prevent creeping due to vibration, the control levers are governed by a bronze friction adjusting nut which is attached to the quadrant

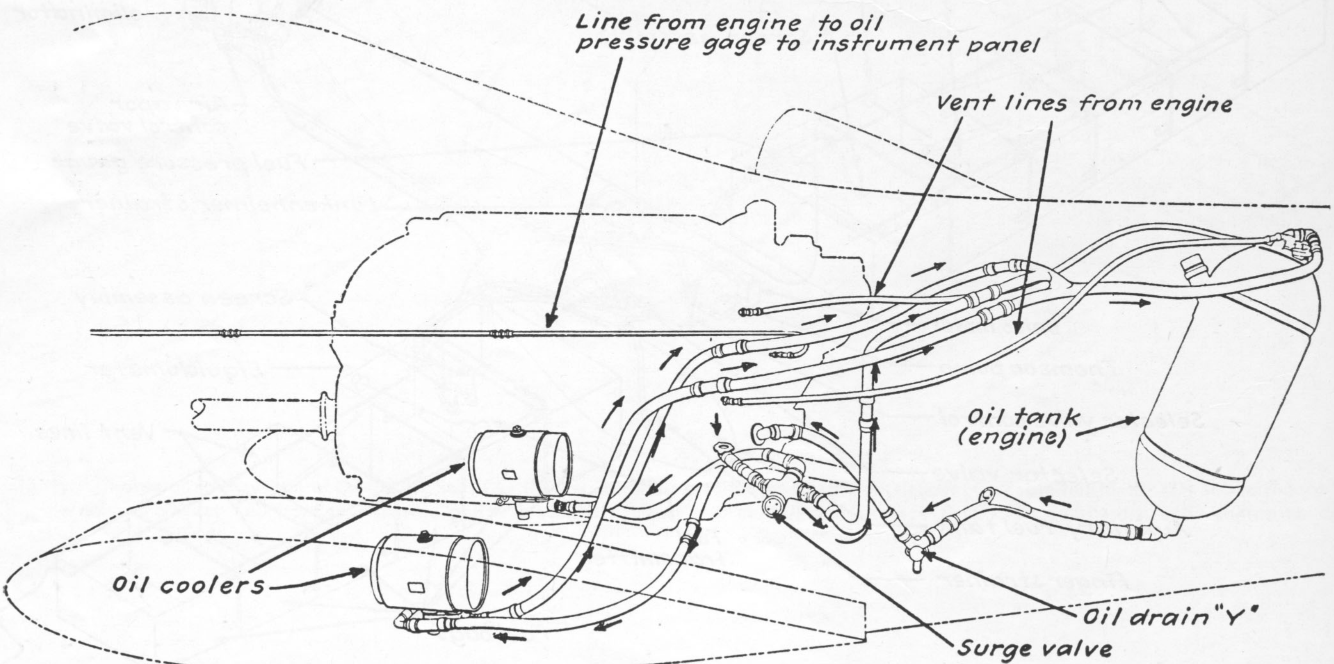


Fig. 3. System for circulating engine oil in the Bell P-39. The propeller reduction gearbox is lubricated by a separate system.

equally to each of the oil coolers and returns through parallel lines connecting to a single line attached to the top of the oil tank. The propeller reduction gearbox is lubricated by a separate oil circulating system with its own tank and pump.

The main oil tank of the engine is constructed of seam-welded magnesium alloy sheet located in the aft fuselage behind the engine accessory bay on the airplane center line (2). The capacity of the tank is 13.8 gal. Oil level is measured by a flexible bayonet-type sound rod located in the tank top casting. It is impossible to fill the expansion space provided within the tank when the airplane is in normal rest position.

The oil-cooling system (3) consists of two oil coolers with separate air ducts located within each outer wing panel and connecting to each cooler in the wing center section (4). The coolers incorporate an independent, fully automatic, thermostatically controlled by-pass valve which circulates oil along the cooler coil until the oil is properly cooled.

Cooling air enters each duct through an individual opening on either side of the fuselage at the leading edge of the wing. Each duct leaves the outer wing panel between the wing front and rear beams and joins the section of duct connected to the coolers. Air exhausts through flap-type shutters located aft of the coolers on the underside of the wing center section. Shutters operate in unison by a lever control located in the right forward face of the turnover beam near the cabin floor and can completely restrict air flow through the coolers.

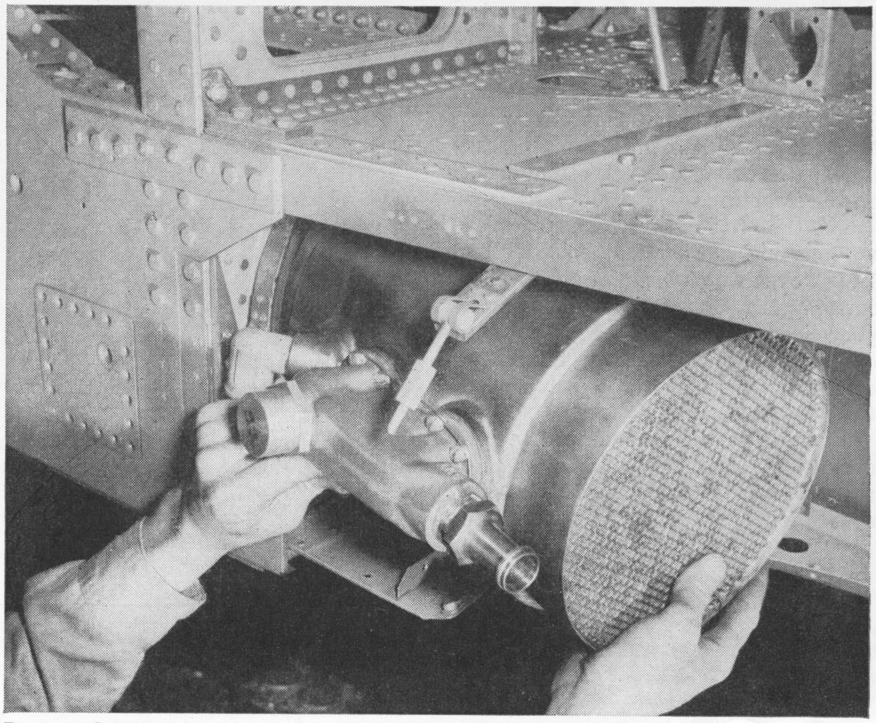


Fig. 4. Cylindrical oil radiators mounted in the aft portion of the wing center section and secured by straps.

A solenoid-operated oil-dilution valve is maintained in the system for cold-weather starting. Dilution of oil is accomplished by the controlled addition of engine oil to the oil-inlet line by operation of a toggle-type switch on the left-hand auxiliary switch panel.

In the oil line from the main engine oil tank to the oil drain Y fitting, an oil thermometer well is installed. A thermometer bulb connects to the well and runs to the oil-temperature gauge on the instrument panel and registers oil "In" temperature.

The oil drain Y fitting is located in the right-hand side of the crank in the oil line which runs from the bottom of the main oil tank to the oil pressure pump. The drain Y fitting is in the lowest part of the oil system which can be drained from this point with the airplane at its normal rest position on the ground.

A by-pass surge valve is incorporated in the oil system. When the plane has been idle for any length of time in cold weather, the oil in the coolers becomes congealed and may cause damage from oil pump pressure when the engine is started. If the oil pressure exceeds 60 psi, the surge valve opens, releases pressure in the coolers, and sends most of the oil flow directly back to the main oil tank. When seepage from the surge valve loosens the congealed oil, the valve closes and allows oil to flow normally to the coolers.

Two engine breather pipes are connected to the engine, one to the top forward end, and one to the top of the accessory housing. Both breather pipes are routed downward to the bottom of the fuselage and exhaust into the slip stream.

All oil lines are of aluminum-alloy tubing with hose connections, nipples, and elbows of standard AAF type. A Pesco oil separator is incorporated in the oil system and is mounted on the left-hand deck of the fuselage. The unit contains no working parts and is sturdily constructed of welded sheet aluminum. Pressure gauge connections and tubular bracket mountings are used throughout.

The reduction gearbox oil tank is constructed of magnesium-alloy sheet with welded seams and is located aft of the gearbox. Oil-pressure lines for this system are aluminum-alloy tubing with brass liners at each connection. The line from the gearbox to its pressure gauge on the main instrument panel is composed of aluminum tubing, copper tubing, and a flexible connection from the line to the gauge.

Republic Seabee

The Seabee's fuel cell (1) is a Goodrich bladder-type bag, made of rubber-impregnated fabric, located inside the hull just forward of the main step and between two watertight bulkheads. The unit rests on a plastic sheet over the hull bottom stiffeners and is fastened to the deck structure by snap fasteners which have sufficient play to facilitate adjustment in securing the bag to the male fastener components on the structure.

The top of the bag is provided with an opening approximately 5½ by 12 in., over which a metal cover plate carrying the filler neck and fuel-level gauge is installed by bolting to the bag and also to the deck skin, which has a corresponding cutout for removal of the fuel cell.

A drain at the bottom of the cell connects to a pipe which runs behind the main step where it is fitted with a drain plug.

Fig. 1. The fuel cell—a rubber-impregnated bladder-type unit—has a cutout for attachment of a plate carrying the filler neck and fuel-level gauge.

Focke-Wulfe FW-190

The entire fuel supply of the FW-190 is carried in two self-sealing tanks suspended by fabric straps in the lower fore fuselage section, with the fore tank, between spars, and having 61.2 U.S. gal capacity; the aft tank, 76.8 U.S. gal capacity (1).

Both tanks are filled from the right side of the fuselage, the filler pipe cover plates being quickly detachable flush units.

Each tank contains a sealed electric pump. The gauges are all electric, the fuel warning light and pump indicator lights being arranged vertically in the center of the lower instrument panel. The fuel supply gauges for each tank are just to their right; the selector gauge to their right. A manually operated fuel selector valve, however, is on the left of the top of the instrument panel. Lines from the tanks to the engine go through the left side of the fire wall.

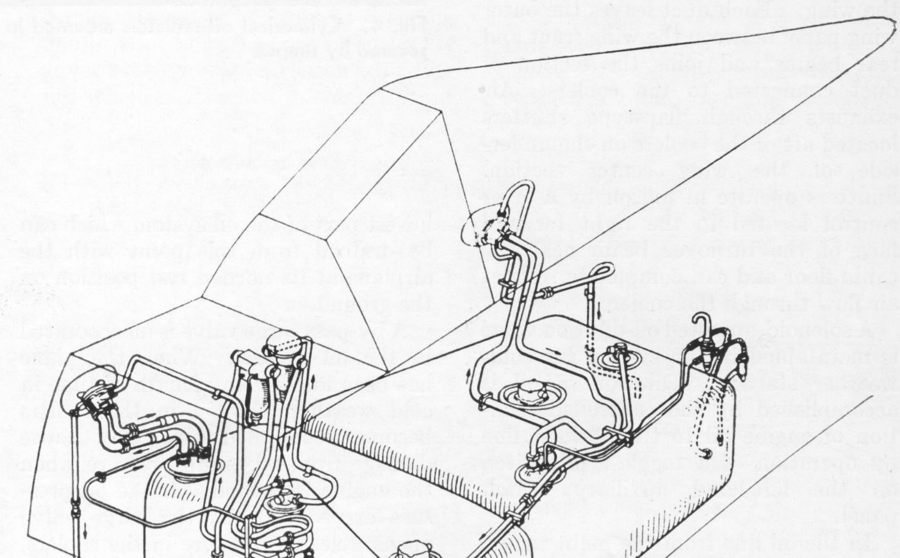


Fig. 1. Complete fuel tank and line arrangement. Electric pumps are used in each tank, and electric measuring gauges are also employed. Filler openings are on the right side of the fuselage inside quickly detachable cover plates. The forward self-sealing tank holds 61.2 U.S. gal; the aft tank, 76.8 U.S. gal. The tanks are separated by the rear spar tie-through member.

Martin 2-0-2 Transport

Eight Mareng, bladder-type fuel cells are located in the outer wing panels of the 2-0-2 for freedom from cabin fire in case of wing damage. These cells eliminate leakage caused by wing deformation and speed maintenance by permitting quick minor repairs without removal.

To conserve ground handling time, underwing refueling accommodations are provided in addition to stand-by fillers on the upper wing surface. One man can make all the connections necessary to refuel the plane at a rate of 200 gpm.

Fueling and defueling valves (1) are included in the system in addition to a fuel booster pump (2).

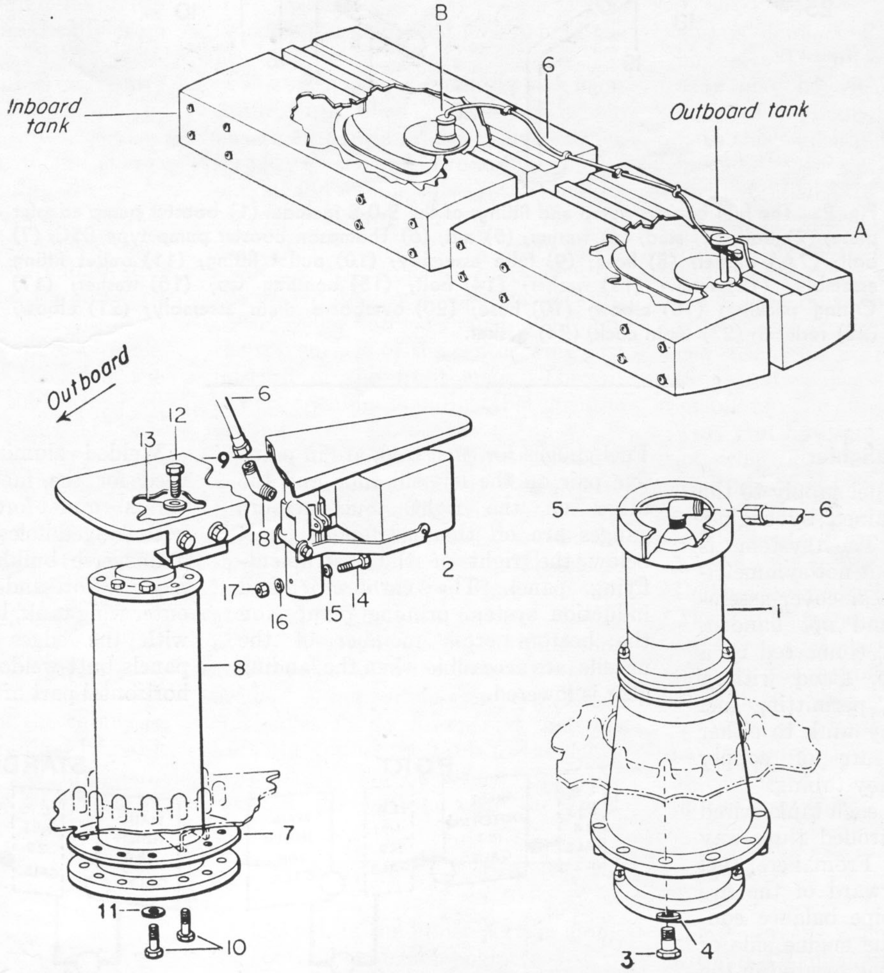


Fig. 1. The Martin 2-0-2 fueling and defueling valve installations shown include the following parts: (1) valve assembly; (2) float assembly; (3) bolt; (4) washer; (5) elbow connection; (6) Aeroquip hose assembly; (7) gasket; (8) surge valve assembly; (9) cover assembly; (10) bolt; (11) washer; (12) bolt; (13) washer; (14) bolt; (15) washer; (16) washer; (17) nut; (18) nipple.

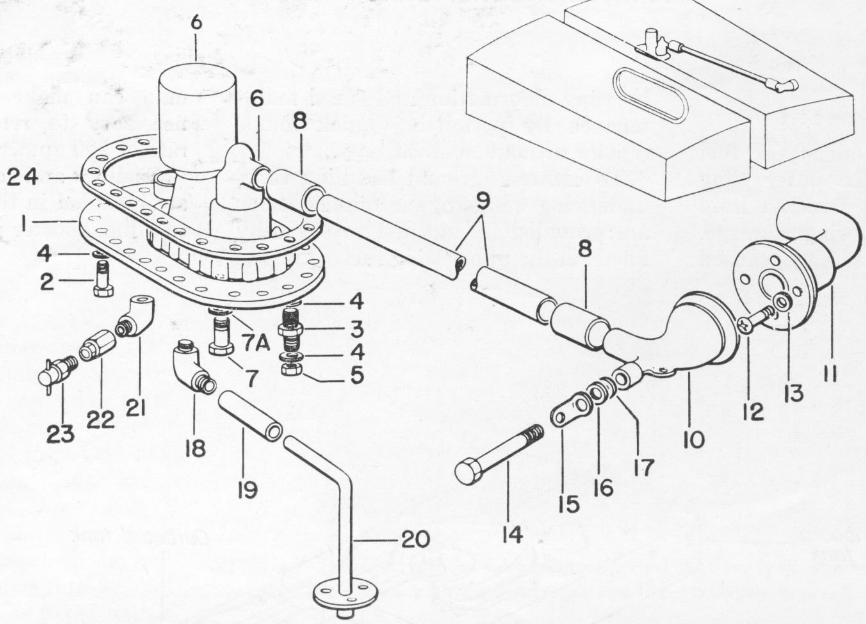


Fig. 2. The fuel booster pump and fittings of the 2-0-2 include: (1) booster pump adapter plate; (2) bolt; (3) stud; (4) washer; (5) nut; (6) Thompson booster pump type B5C; (7) bolt; (7A) washer; (8) hose; (9) tube assembly; (10) outlet fitting; (11) outlet fitting assembly; (12) screw; (13) washer; (14) bolt; (15) bonding tap; (16) washer; (17) O-ring packing; (18) elbow; (19) hose; (20) overboard drain assembly; (21) elbow; (22) reducer; (23) drain cock; (24) gasket.

Bristol Beaufighter

The Beaufighter's fuel supply to the carburetors is maintained by engine-drive pumps (1). The system is similar on each side but not symmetrical since the engine rear cover assemblies are identical and not handed. The tube systems are connected by a suction balance pipe, fitted with a pilot-controlled cock, permitting fuel to be drawn from any tank to either engine. Pipe lines are of copper Superflexit or light-alloy tubing.

Fuel is drawn from each tank, wired open, to a pilot-controlled three-way cock in the nacelle. From here, fuel passes to a filter forward of the fire wall. The suction pipe balance connection is made at the engine side of the pilot-controlled cock located in the leading edge of the center wing between fuselage and left engine. The engine pump draws fuel from the filter and delivers it through a pressure regulator to the carburetor. A connection for the fuel-pressure gauge is made at the carburetor and for the priming system at the filter.

The two main fuel tanks are carried between the wing spars on each side. Fuel gauges for each tank are in pairs, one pair on the left sill tube and the other on the right. Fuel-pressure gauges are on the instrument panel below the right of the instrument-flying panel. The carburetor and induction system priming pumps, on the bottom cross member of the nacelle, are accessible when the landing gear is lowered.

Welded aluminum construction is used for the fuel tanks (2). Transverses and fore-and-aft bulkheads with flanged holes are inside each tank. Transverse bulkheads, also an intermediate fore-and-aft bulkhead on the outer wing tank, have T-section flanges with the edges of the main shell panels butt-welded to the edges of the horizontal part of the T sections. The

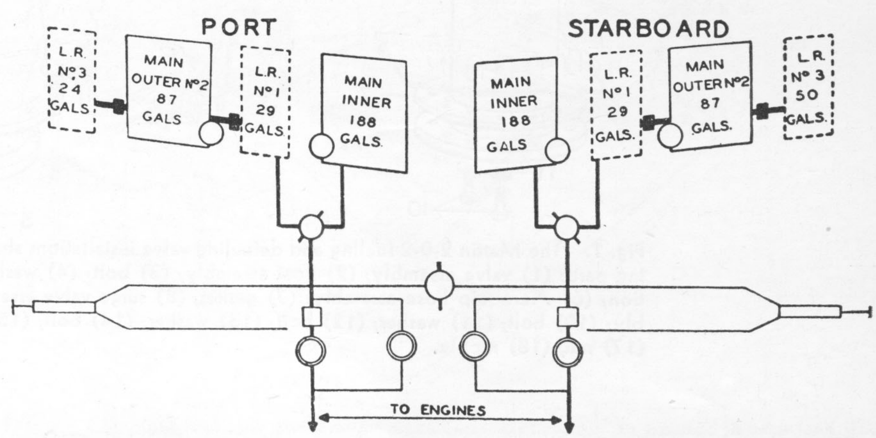


Fig. 1. Fuel supply is maintained by engine-driven pumps. Tube systems are connected by suction balance pipe with a pilot-controlled cock. Fuel is filtered forward of the fire wall. Long-distance (L.D.) extra tanks are fitted when required.

fore-and-aft bulkheads have angle flanges on both sides of the plates, which are riveted to the transverse bulkheads, but no attachment of these bulkheads is made to the shell. Edges of the tank ends are welded to the shell and to a strip on the middle transverse bulkhead. Filler caps, vent adaptors, inspection doors, fuel-contents gauge attachments, and sumps are fitted on the tanks, which are protected by a self-sealing covering.

The outer and center wing tanks are strapped to bearers riveted to detachable panels on the undersurface of the wings and bolted to brackets at the spars.

A jettison valve, under the outer tanks, is operated pneumatically from the instrument panel. Fuel is jettisoned through piping under the outer wing. Later models provided for jettisoning the fuel from all tanks.

The oil feed-pipe line to the engine leads from the tank sump direct to the pressure pump on the engine. Return oil passes through an oil cooler on struts at the inboard end of the outer wing L.E. From the forward end of the cooler, the oil returns to the top of the hopper in the tank. After starting up, when the oil in the tank is cold and thick, the warmer oil from the engine is recirculated, supplemented by a small quantity only of cold oil that enters the sump through the holes at the bottom of the hopper. When the oil in the tank has become warm, a greater proportion of it enters the sump. Centrifugal oil clearers are incorporated in the engines.

A thermometer connection is on the feed pipe, and a pressure gauge connection is made on the engine rear cover. Excess length of the tubing is wound round a spool mounted inboard of the nacelle behind the fire wall. A cock for draining the oil system is

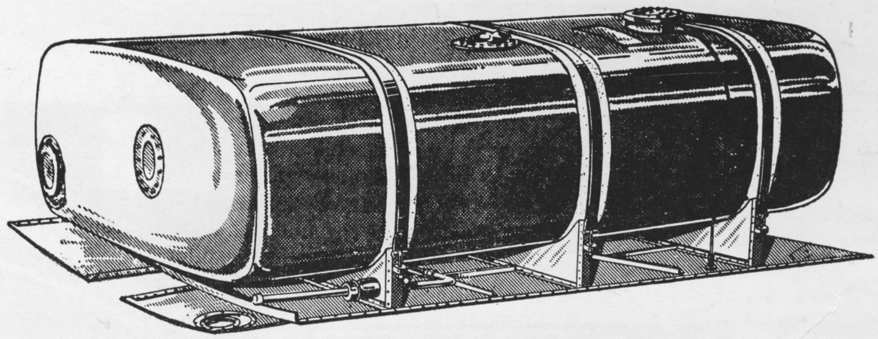


Fig. 2. Welded aluminum fuel tanks have self-sealing covering to protect the plane from fire hazards.

fitted in the main feed pipe behind the fire wall.

The oil cooler is of the two-element drum type, each element of which has a separate relief valve which by-passes the oil around a jacket outside the cooling tubes if the pressure exceeds a certain figure.

Each relief valve has a different setting which is clearly marked on it. Air is collected by an opening forward of the cooler and is exhausted through the top surface of the center wing just forward of the front spar. The air outlet opening is adjustable on the ground.

Each oil tank is constructed of welded aluminum and is strapped to the top of the center wing under the engine nacelle top panel. Inside the tank are two transverse bulkheads in line with the straps; they are not attached to the shell but are tightly fitted. Vertical fore-and-aft bulkheads are fitted between the transverse bulkheads. A hopper, having arge-diameter holes in its lower end, extends from the top of the tank to the sump at its base. The oil return enters the tank at the bottom near the front and is connected to the top of the hopper. The filter in the sump of the tank may be withdrawn through the cover of the hopper.

In this tank the filler cap is situated in such a position that the tank cannot be overfilled. It also assures the correct air space. A dipstick is provided adjacent to the filler cap for gauging the depth of fuel.

For long-range flying, such as coastal patrol and convoy work, provision has been made for additional fuel tanks in the wings. They are arranged as follows: one 50-gal tank in the right-wing gun bay; one 24-gal tank in the left-wing gun bay; and one 20-gal tank on each side of the outboard ends of the center wing.

The center-wing tank in each wing is connected to the outer series through the three-way cock in the engine nacelle. The supplementary wing tanks also are connected with the fuel balance pipe in the engine nacelles, through Superflexit hose. They are vented through a common pipe which is carried along the wing to the fuselage and terminates near the fuselage roof on the right side.

Douglas A-20

In the A-20, a separate lubrication system (1) is provided for each engine. The oil tanks have a net capacity of 23 gal plus a 3-gal air space, and they are of self-sealing material designated as U.S. Rubber Co. material No. 143.

A partial circulation hopper is in each tank. Oil coolers with automatic self-closing shutters are provided in each nacelle, where the oil tanks also are located, in the upper portion along the center line of each engine.

Each lubrication system has electrically controlled dilution, and oil tanks incorporate provisions for the installation of an electrically operated immersion-type heater, supplied with current from an external source.

Fuel is carried in two pairs of wing tanks and two removable fuselage tanks. The wing tanks are equipped with detachable sump plates and finger screens which are removable without disconnecting the fuel lines.

The main fuel supply is drawn from the wing tanks through finger screens at each end of the main tanks and interconnected by means of a selective sump valve for each tank. Wing tanks are individually wanted, and overflow is discharged at the aft end of each nacelle. Each inboard tank is provided with an emergency dump valve.

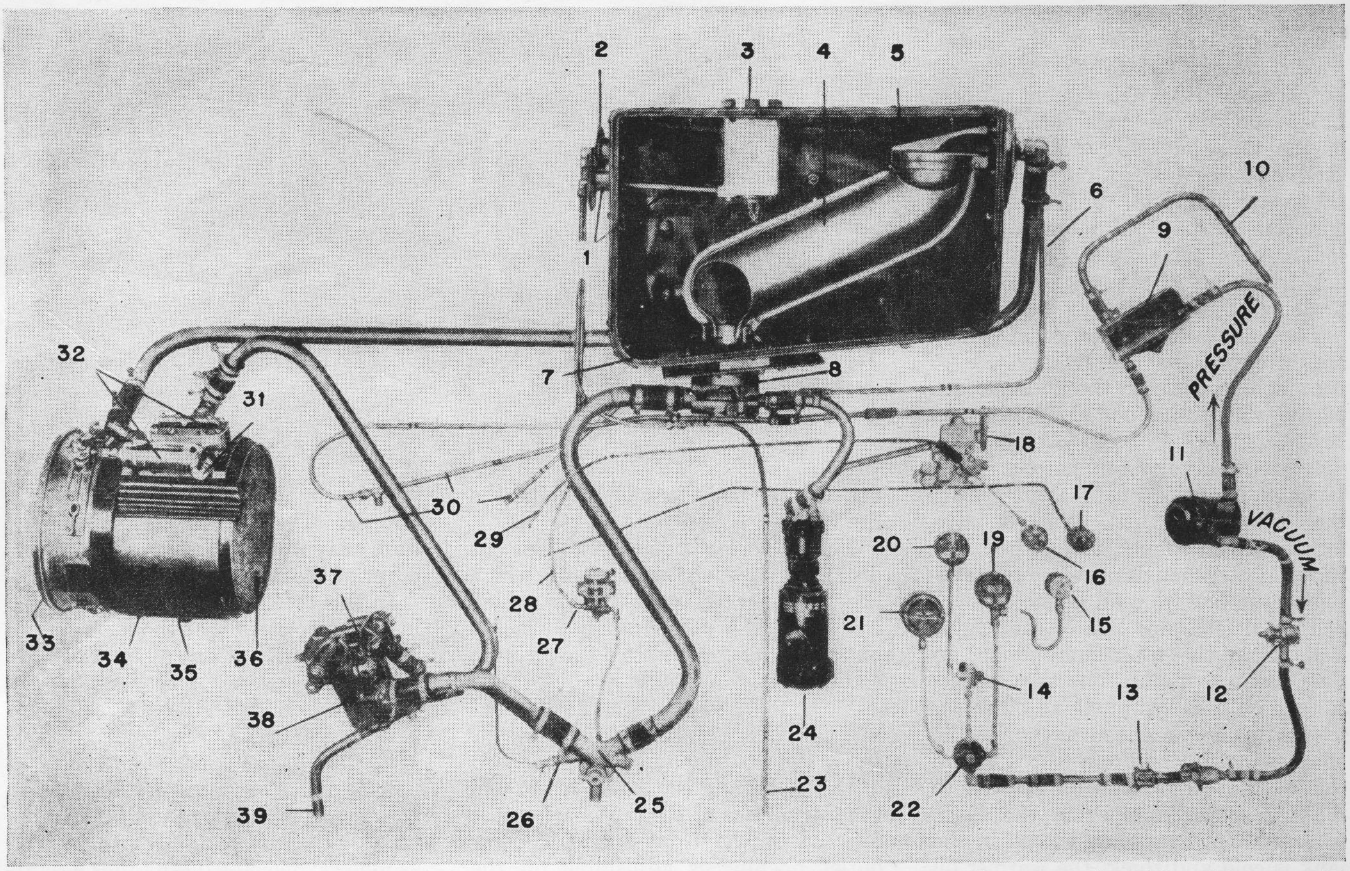


Fig. 1. The engine oil systems are separate; hopper type, to free oil from air and dilution vapors. (1) Filler cap overflow; (2) tank top vent; (3) filler cap; (4) hopper; (5) supply tank; (6) vent; (7) divided channel standpipe; (8) sump adapter; (9) oil separator; (10) line to atmosphere; (11) vacuum pump; (12) suction relief valve; (13) flapper valve; (14) turn-and-bank relief valve; (15) suction gauge; (16) oil-pressure gauge; (17) oil-temperature gauge; (18) propeller feathering governor; (19) gyro-compass; (20) turn-and-bank indicator; (21) artificial horizon; (22) master relief valve; (23) filler cap overflow; (24) propeller feathering electric pump; (25) Y drain; (26) oil-temperature bulb; (27) oil-dilution solenoid valve; (28) line from carburetor; (29) oil-pressure line; (30) overflow to engine sump; (31) viscosity valve regulating screw; (32) viscosity valve; (33) shutter; (34) oil cooler; (35) sump plug; (36) cooling tubes; (37) pressure regulating screw; (38) engine oil pump; (39) scavenger line to engine pump.

The fuselage tank consists of two separate containers installed above the bomb bay and interconnected by lines which equalize the level of fuel in them. An electrically driven booster pump, controlled from the cockpit, and a pump adapter with a flange to provide a sump, complete the installation. Vents are interconnected and discharge at the high point of the plane in normal flight or at rest on the ground.

Normally, each power plant is supplied by its own independent fuel system, but these may be interconnected by the pilot on either the suction or pressure side of the engine fuel pumps, so that each engine may be supplied from any wing tank, or both engines can be supplied by one fuel pump.

The fuselage fuel tank is connected into the left-hand tank selector valve, so that fuel from the fuselage tank may be supplied to either or both engines.

The engine-driven fuel pumps are mounted directly on the engines, and fuel is supplied from the suction side of the pump through selector valves and strainers. Hand fuel pumps and cross-feed valves are located in the fuselage, with fuel valves operated by cable and rod controls, and the hand pumps by rod controls.

Gauges are of the electric remote indicating type and are located on the instrument panel. The transmitter unit is installed in the tank.

Weights of the fuel system: tanks, 810 lb; piping and equipment, 468 lb; total, 1,278 lb. Oil system: tanks, 131 lb; piping and equipment, 213 lb; total, 344 lb.

North American B-25 Mitchell

Each engine of the B-25 is provided with an independent fuel system (1). The main fuel-supply source is four self-sealing tanks, two located in each wing center section between the fuselage and the engine nacelle.

Front and rear tanks on each side are connected by a line from the rear tank to an adaptor to which a booster pump is attached. A check valve permits fuel to flow from the rear to the front tank and then to the engine, but prevents fuel from returning to the rear tank.

Booster pumps are operated by switches on the pilot's control pedestal

switch panel. An auxiliary fuel supply also is obtained from six small self-sealing tanks, three in each wing center section outboard of the main tanks. The front and outboard tanks in each group are connected with the rear auxiliary tank by a line from each tank aft through the nacelle to an electrically operated transfer pump. The transfer pump draws fuel simultaneously from the three auxiliary tanks and pumps it through a line to the front main tanks. Each engine is fitted with type G-9 rotary vane positive-displacement type of fuel pump located on the right-hand aft end of the engine.

An independent oil system, identical

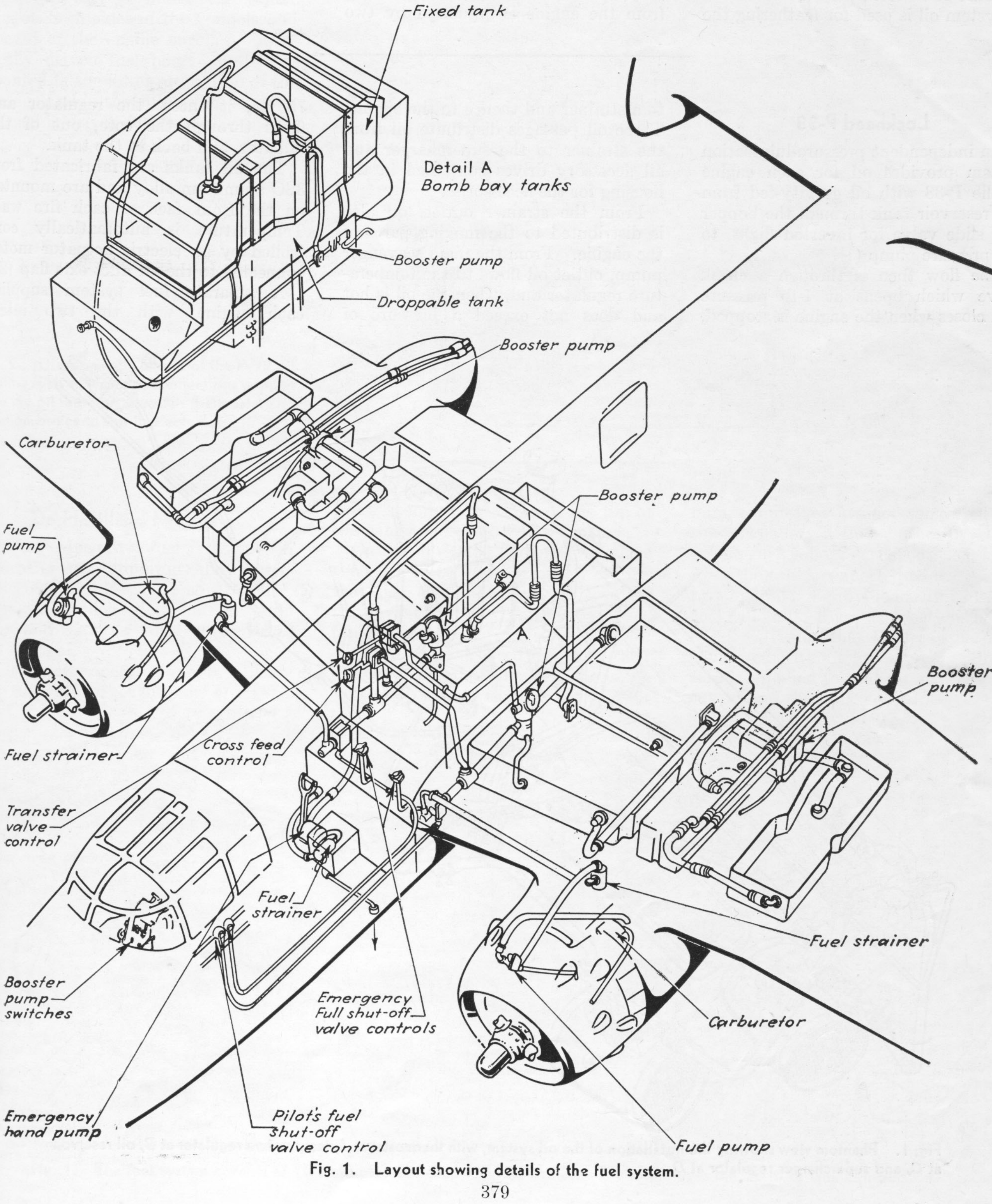


Fig. 1. Layout showing details of the fuel system.

except for minor variations in oil line routings, also is provided each engine. A self-sealing tank is installed in the wing section aft of the fire wall. Oil flows from the tank to the engine-driven oil pump, to the engine under pressure of 80 to 90 psi.

System oil is used for feathering the propellers and is taken from the circulating oil by a pump, mounted on the fire wall, which delivers the oil under pressure to the propeller governor mounted on the front of the engine.

Temperature of the oil returning from the engine is regulated by two thermostatically controlled type C-8 oil-temperature regulators mounted on the center portion of ducts which open in the wing leading edge and have outlets through the upper surface of the wing just forward of the wing flaps.

Lockheed P-38

An independent pressure-lubrication system provides oil for each engine of the P-38 with oil gravity-fed from the reservoir tank through the hopper and slide valve for inverted flight, to the pressure pump (1).

The flow then is through a check valve which opens at 1-lb pressure and closes when the engine is stopped, to a strainer and thence to the engine. Three oil passages distribute oil from the strainer to the supercharger and all accessory drives contained in the housing for the accessories.

From the strainer outlet, oil also is distributed to the moving parts of the engine. From the main scavenger pump, outlet oil flows to the temperature regulator and, when the oil is hot and does not exceed a pressure of 75 psi, it enters the regulator and flows through the core, out of the radiator, and back to the tank.

The oil tanks are fabricated from 3SO aluminum alloy and are mounted on the front face of each fire wall. Temperature is automatically controlled by an electric actuator motor connected to the air duct exit flap (2).

A separate fuel system supplies each engine, with the two inter-

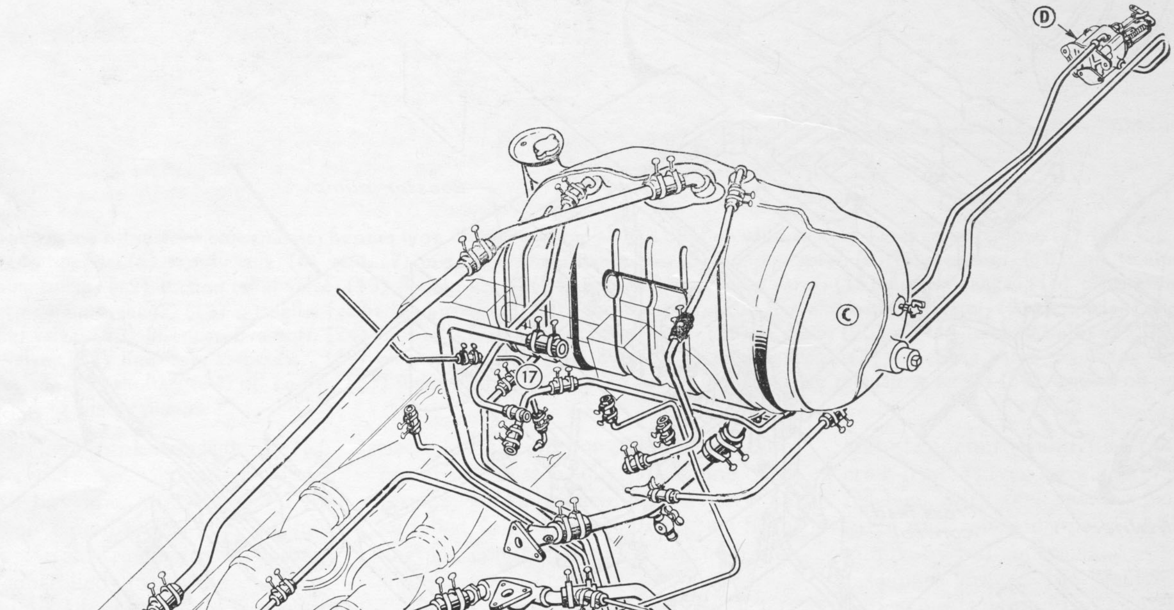


Fig. 1. Phantom view showing the installation of the oil system, with thermostat at *A*, temperature regulator at *B*, oil reservoir at *C*, and supercharger regulator at *D*.

connected so that fuel from any tank, except the outer wing tanks, is available for either engine.

Three tanks supply each engine: main, reserve, and outer wing leading edge. In addition, droppable fuel tanks are carried under the center wing on both sides of the gondola and inboard of the engine nacelles. Electrically driven fuel boost pumps are mounted in the lower aft section of the fuselage and in the outer wing to assist the engine-driven fuel pumps.

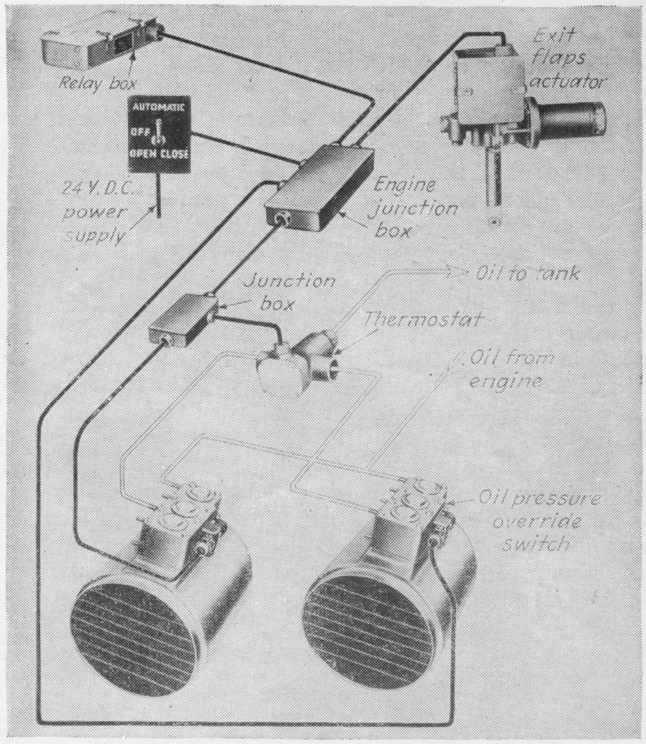


Fig. 2. **Diagrammatic layout of the P-38 oil cooling system, showing connections running from the oil radiators, through thermostat and junction boxes to the flap actuator.**

De Havilland Mosquito

In the Mosquito, fuel is carried in five pairs of aluminum alloy tanks protected by self-sealing covering (1). They all are housed within the main wing and have a total capacity of 674 U.S. gal.

Electrically operated gauges indicate the contents of each pair of tanks. Filler openings are through the top of the wing or fuselage for all tanks.

On the starboard side of the fuselage there is a fuel-collection gallery casting that has disk-type nonreturn valves to prevent the flow of fuel from one tank to another.

Outboard tanks feed direct to their respective engines through the main control cocks and through the booster pumps, but they are not connected to the fuel gallery with the other tanks.

The fuel gallery feeds both engines from the tanks connected to it. Each pair of tanks is provided with a drain cock, and all delivery connections have check valves so that they can be disconnected without loss of fuel. Pressure is supplied to tanks, but it can be cut off and the tank vented.

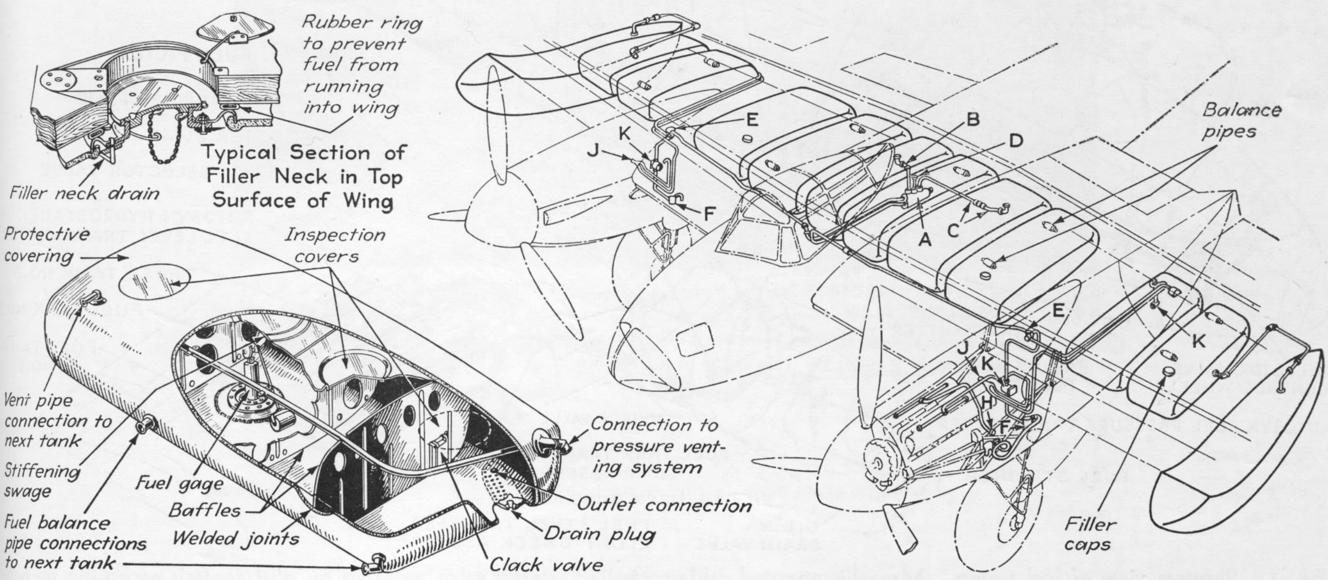


Fig. 1. The fuel system consists of 10 tanks plus end drop tanks, as shown. The insert gives the detail of tank construction.

Curtiss C-46 Commando

In the original design of the C4-6 fuel system (1), safety was a prime consideration, for all tanks are located well away from the fuselage in outer wing panels, outboard of the nacelles and the solid splice plate. Each engine has its own fuel system, but the two are interconnected by a cross-feed line.

The fuel tanks are all aluminum alloy, with wing tanks being set in padded cutouts in the first and fourth ribs outboard of the splice panel.

The ribs and supports are so designed that no flexing or bending can be transmitted to the tanks from the surrounding structure. Fuel expansion of 3 per cent of capacity is provided, and filler caps have pressure relief valves. Sump capacity is 2 pt per 100 gal, so designed that water or foreign matter cannot be taken into the tank outlet.

In the prototype, fuel went to the engine only from the fore tank via transfer pumps having a 7-gpm capacity, accomplished by the pilot's starting the transfer pumps.

In production models of the plane, however, this was changed so that a cable-controlled selector valve, operated from dual controls, is accessible to both pilots, enabling them to select and draw from any tank. All fuel system pipes are 52SO aluminum, except for stainless-steel cross-feed lines and fittings.

Standard C-46 fuel capacity is 1,400 gal—242 gal in each of two fore tanks, 283 in the center tanks, and 175 in each of two aft tanks—and an additional 800 gal may be carried in eight fuselage tanks for long-range operations (2).

Separate oil systems (3) are provided for each engine, the tanks having a capacity of 40 gal each, with expansion space of 12½ per cent of rated capacity. Tanks, set just aft of the fire wall at the outboard side of the nacelle, are so arranged that expansion space cannot be filled while the tanks themselves are being filled.

Oil radiators are drum type, 15 in. in diameter, mounted in the lower portion of the nacelle between the engine and the cowl flap (4). Each system has an automatic temperature-control valve and provisions for oil dilution for cold-weather starting. Added oil temperature control is obtained through controllable flaps in each exit duct. To facilitate maintenance, either the tanks or the radiators may be removed with the engine and mount left in place.

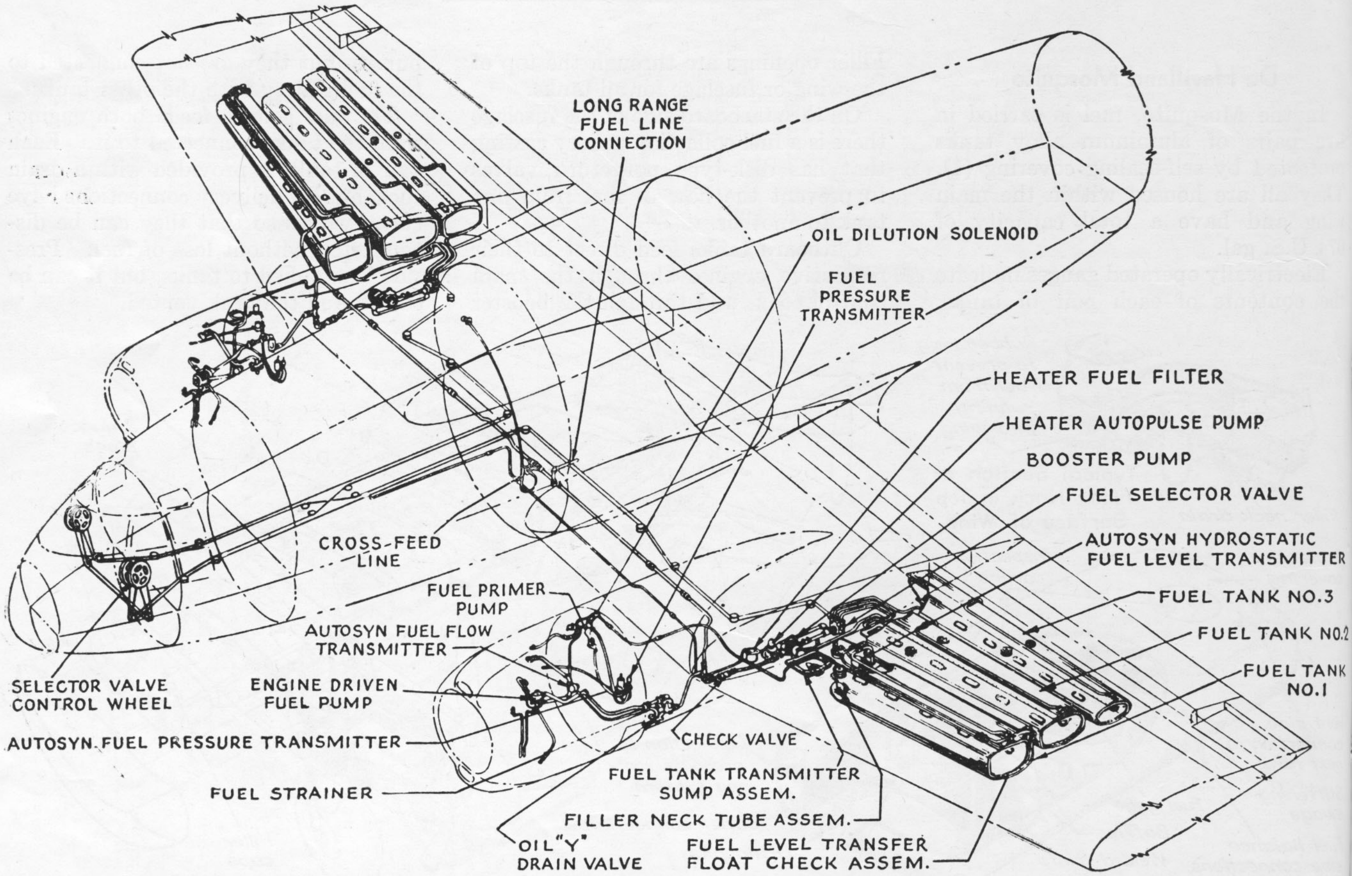


Fig. 1. Phantom view of fuel system. Manually operated cable-controlled selector valve, actuated by dual controls accessible to both pilots, permits selection of fuel from any desired tank in standard 1,400-gal capacity system.

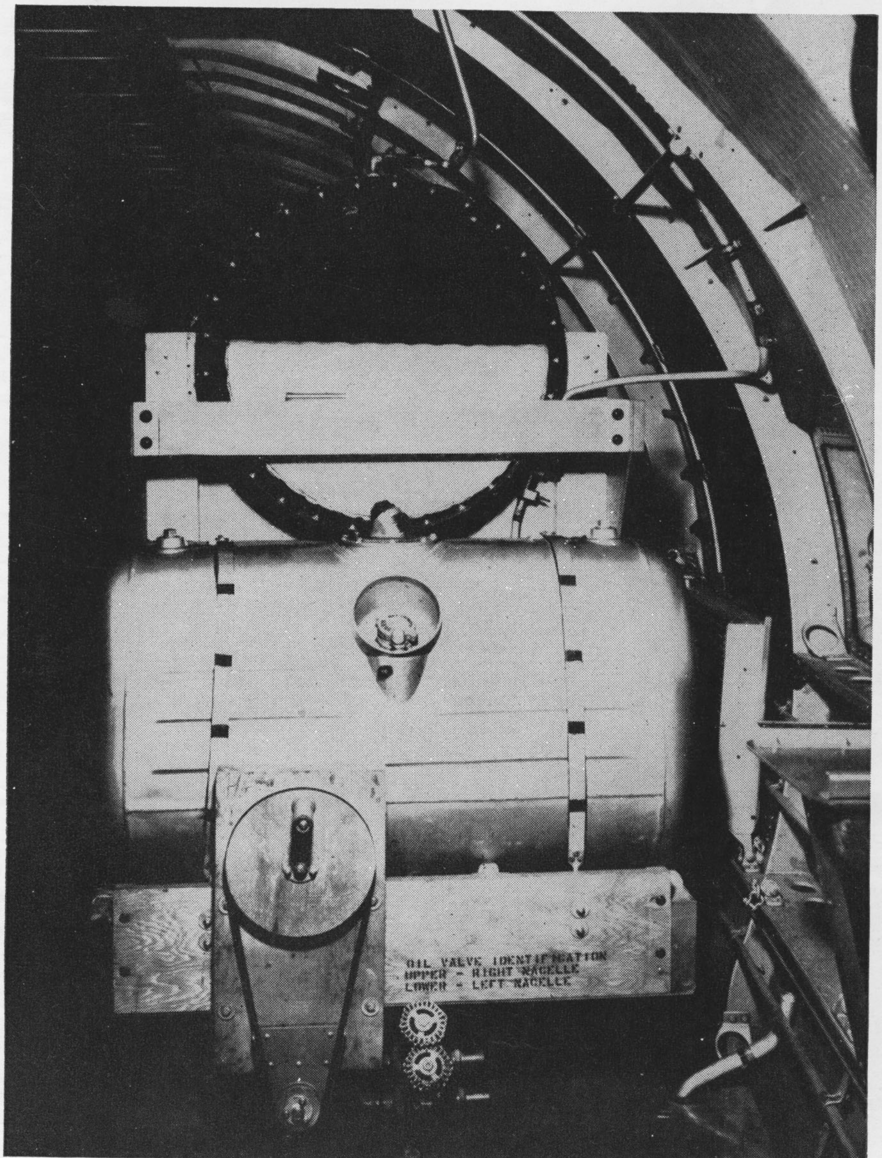


Fig. 2. For long-range operations, the Commando's normal 1,400-gal capacity may be increased by 800 gal by the installation of extra fuselage tanks mounted in lightweight plywood cradles. Here in the main cargo compartment, are shown one of the gasoline tanks and a 39.8-gal oil tank, with hand pump to transfer oil to the regular oil tanks in the engine nacelles.

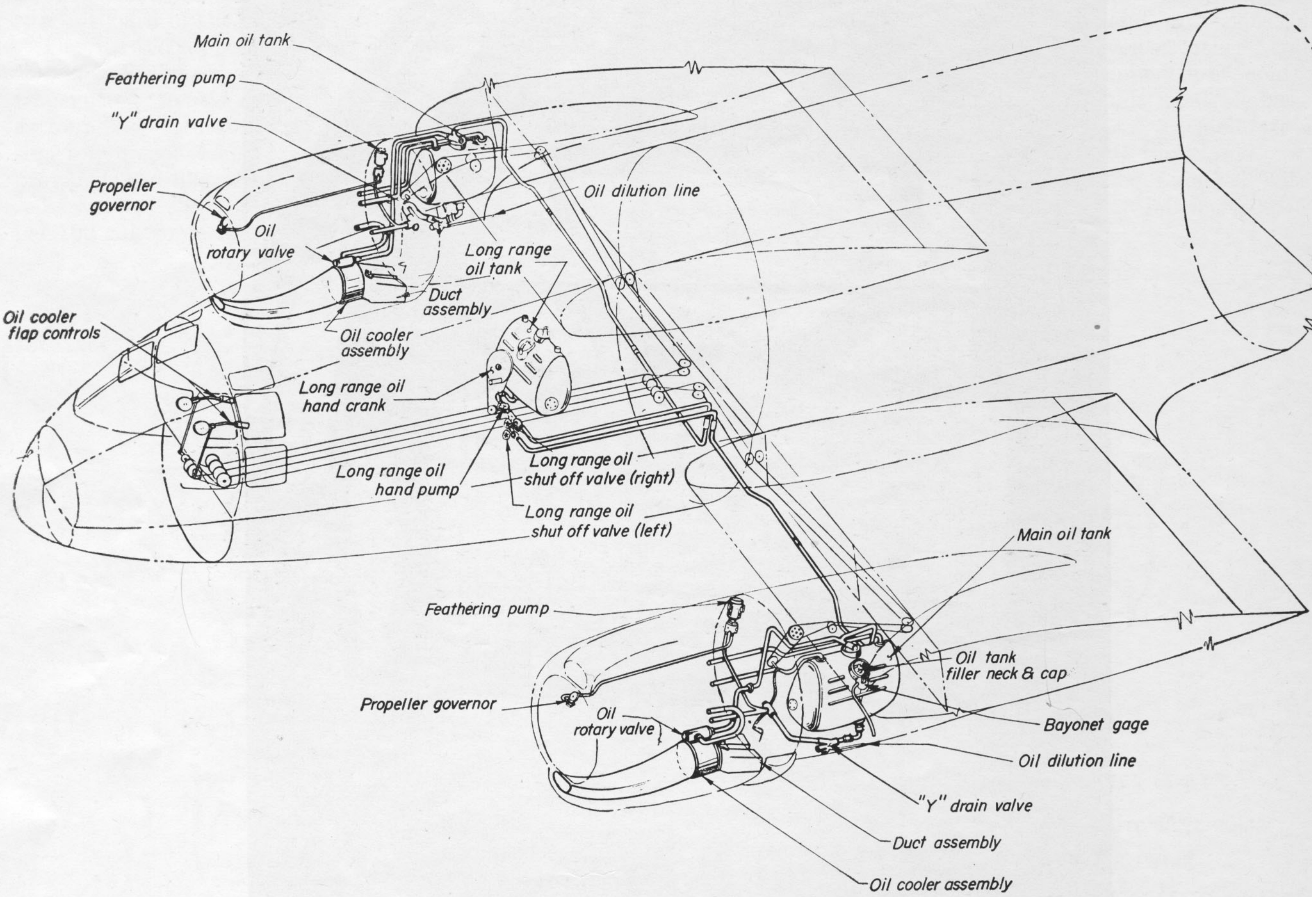


Fig. 3. Phantom view of the oil system, including fuselage tank installation for long-range operation.

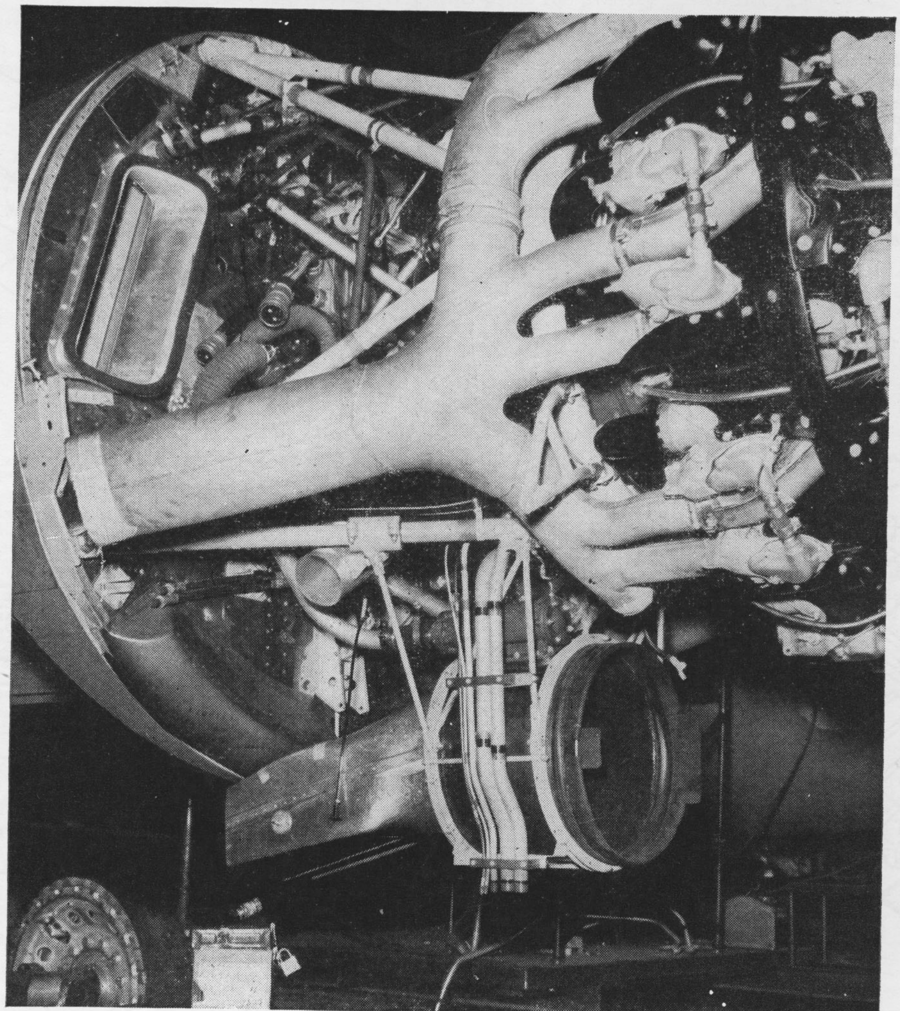


Fig. 4. View from below, showing the installation of a drum-type oil radiator, 15 in. in diameter, mounted in the lower portion of the cowling between engine and cowling flap. Each oil system has its own flaps, operated individually from the cockpit, for added cooling control.

Boeing B-17

The fuel storage system of the B-17 (1) includes 24 leakproof tanks. Installed in each inner wing panel, between the nacelles and to the rear of the front spar, the two largest hold 425 gal each. A 212-gal tank is installed in each inner wing between the 425-gal tank and the rear spar. A 213-gal tank is located on each side between spars, inboard of the inboard nacelle. Nine smaller feeder tanks, or Tokyo tanks, are located on each wing outboard of the outboard nacelles, four in the inner wing and five in the outer wing panel.

A droppable leakproof tank of 410 gal can be carried on each side of the bomb bay in place of corresponding bombs.

Fuel distribution is through four systems, each supplying one engine. By means of a reversible electrically driven fuel-transfer pump, selector valves, and interconnecting lines, fuel can be transferred from any auxiliary or engine tank to any other engine tank. Fuel booster pumps are installed in the outlets of four engine tanks to combat vapor lock at high altitudes and to supply extra fuel for take-off.

A fuel shutoff valve, electrically controlled, is installed in the line between each fuel boost pump and the engine to prevent flow to a severed line in a nacelle or engine section. From the shutoff valve, fuel passes through a strainer mounted on the forward side of the fire wall and enters the engine-driven fuel pump. From there it passes through the carburetor.

The oil system (2) lubricates the engines, aids as a coolant in transferring heat from the engines, supplies hydraulic pressure to assist in propeller speed control, and feeds oil to the propellers, propeller governors, and feathering pumps.

Each engine has its independent oil system. A self-sealing oil tank with a capacity of 37 gal is located in each nacelle aft of the fire wall and is designed for a maximum diving angle of 25 deg.

Oil cooler and temperature regulators

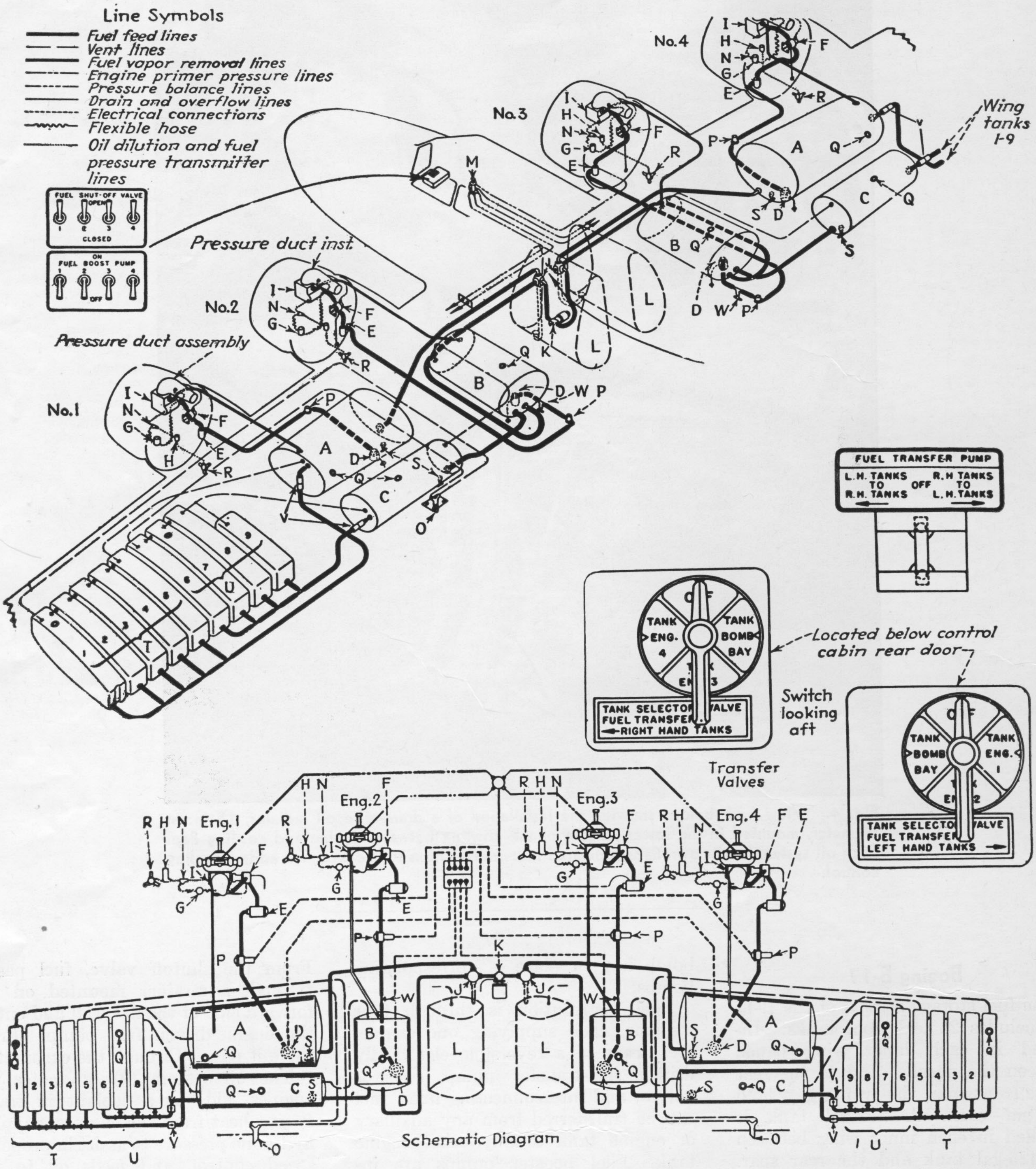


Fig. 1. Diagrammatic representation of the fuel system: (*A*) Nos. 1 and 4 engine tank; (*B*) Nos. 2 and 3 engine tank; (*C*) feeder tank; (*D*) booster pump; (*E*) fuel strainer, inboard; (*F*) engine fuel pump, type 6-9; (*G*) fuel pressure transmitter, type C 14A; (*H*) oil-dilution valve; (*I*) carburetor; (*J*) fuel-transfer selector valve; (*K*) transfer pump; (*L*) bomb-bay fuel tank; (*M*) primer, four engine fuel; (*N*) twin restriction fitting; (*O*) tank vents, underside of the wing; (*P*) fuel shutoff valve; (*Q*) tank filler neck; (*R*) oil drain-cock assembly; (*S*) drain cock; (*T*) outboard wing tanks No. 1 to 5; (*U*) inboard wing tanks No. 6 to 9; (*V*) valve-swing check; (*W*) tank drain valve.

are installed in the leading edge of the wings. The oil pump, Cuno filter, and scavenger pump are incorporated in the engine. Individual oil tanks of 1½ gal capacity and with ½-gal expansion space are provided for lubrication of each supercharger. Propeller feathering motors and pumps are mounted on the forward side of the fire wall of each of the nacelles.

Oil flows from the tank by gravity and suction to the engine-driven oil pump which forces the oil under pressure through the filter to the engine. The oil then drops down to the sump, where it passes through a screen and is picked up by the engine-driven scavenger pump, forced through the oil cooler and returned to the tank.

Oil for propeller feathering is obtained from the oil tank sump from a stand-by reserve. The feathering pump draws the oil from this source and forces it under pressure to the feathering valve in the propeller governor.

An oil-dilution fuel line enters the main oil OUT line from the tank at a Y-cock drain valve.

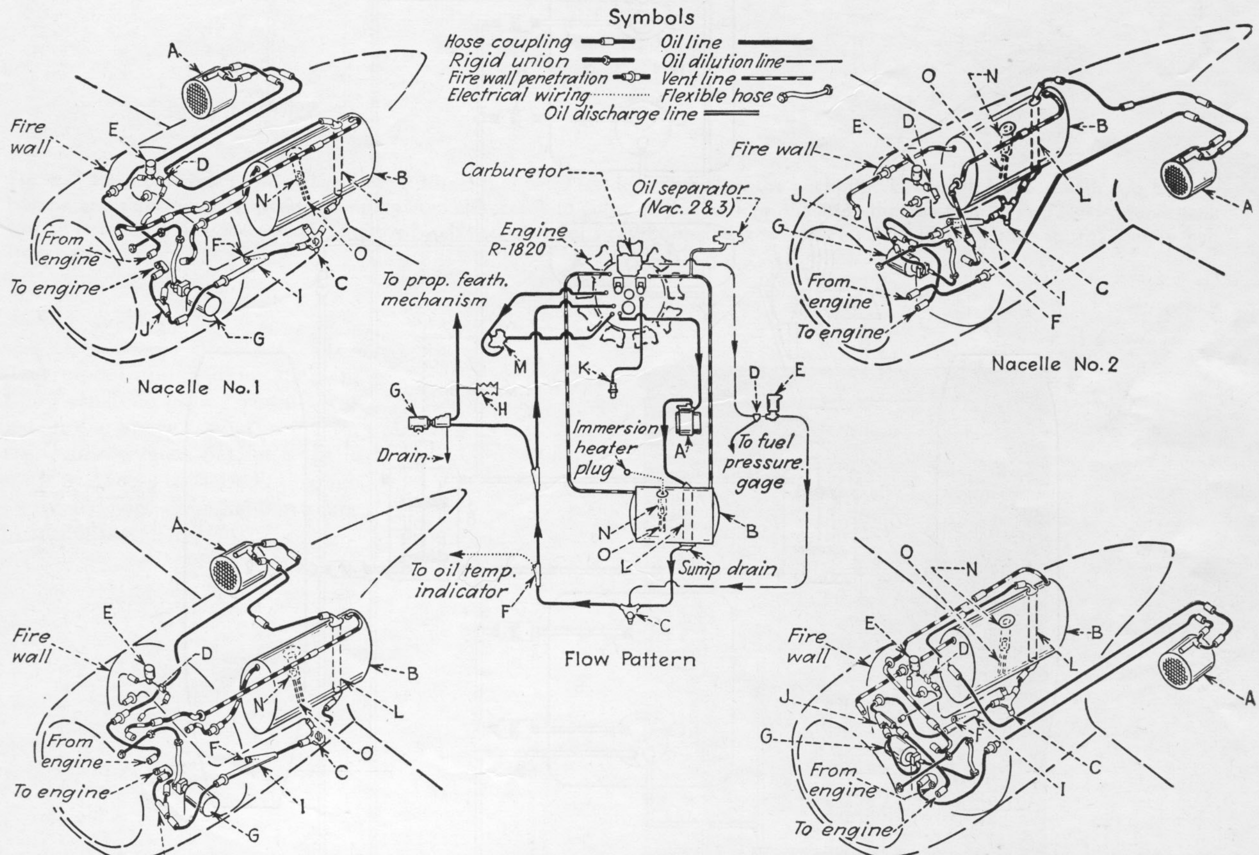


Fig. 2. Diagrammatic representation of oil system: (*A*) oil-temperature regulator; (*B*) oil tank; (*C*) drain valve; (*D*) restriction fitting; (*E*) oil-dilution valve; (*F*) oil-temperature bulb (electric resistance); (*G*) propeller feathering pump; (*H*) pressure cutout switch (type 4G8-G6C); (*I*) tube assembly (welded); (*J*) tube assembly (welded); (*K*) oil-pressure transmitter (type B-9A); (*L*) oil-temperature accelerating well; (*M*) supercharger regulator; (*N*) heater receptacle assembly; (*O*) immersion oil heater.

Messerschmitt Me-262

The Me-262 jet-fighter fuel system (1) consists of two 238-gal main tanks (2) plus a 53-gal reserve and, at least in the design plans, an auxiliary tank of about 170-gal capacity.

Both self-sealing main tanks have plywood coverings and are suspended by two straps on the ends of which are bolts that go up through pressed fittings riveted to the inside of the fuselage skin about two-thirds of the way up the side. Nuts are put on the bolts through access holes through the fuselage skin, with the holes covered by doped-fabric patches.

Each of the main fuel cells has two booster pumps (3) and the reserve tank has one, the system being so arranged that fuel can be pumped from any tank to either engine, or fuel from the rear tank can be pumped to the front.

The reserve tank (at least some of these have not been self-sealing) goes just in front of the main spar. It is trapped to a single-skin panel, 19¾ in. deep by 66¼ in. wide, that is reinforced by six hat-shaped stiffeners and is attached to the fuselage by flat screws placed about 1¾ in. apart.

Evidence that the Nazis attempted to get more range out of the plane is shown by plans for installing the 170-gal auxiliary tank aft of the rear main cell. It is not known how extensively, if at all, this plan was carried out, for the craft studied was

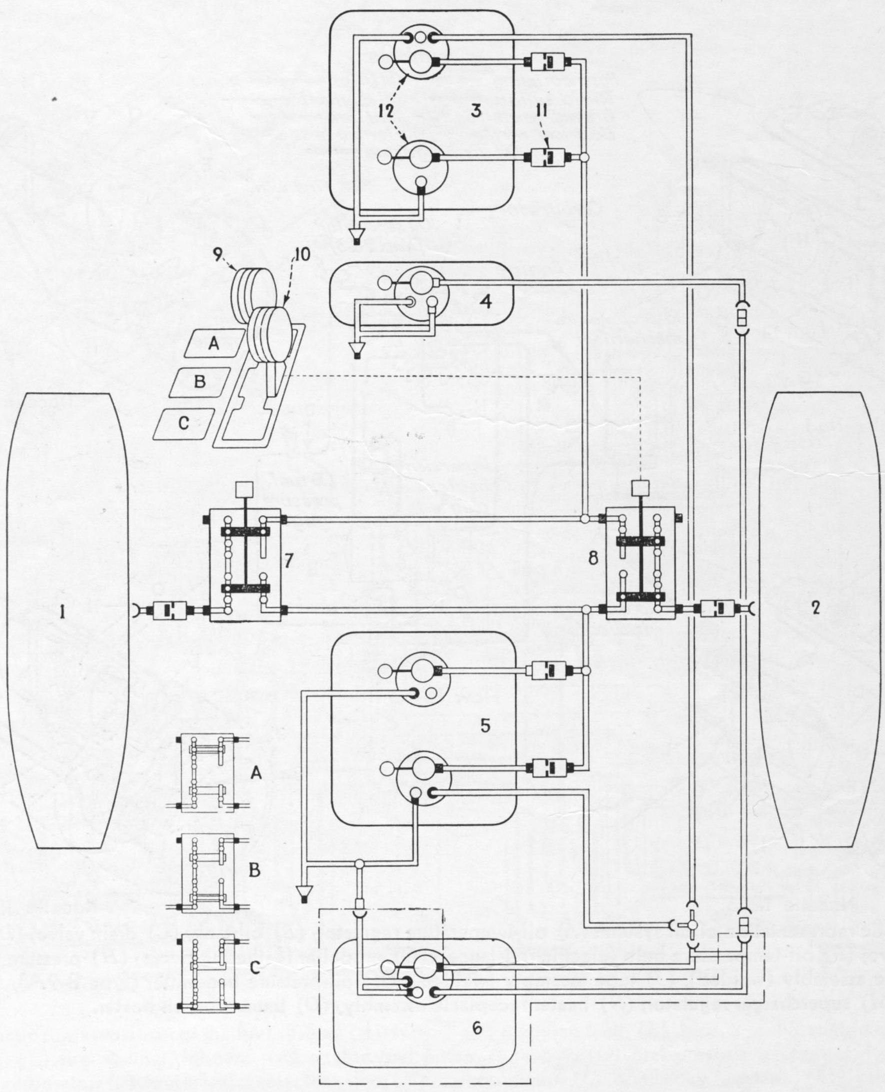


Fig. 1. Schematic diagram of the Me-262 fuel system showing: (1) and (2), left and right engines; (3) fore fuel tank; (4) auxiliary fuel tank; (5) aft fuel tank; (6) extra auxiliary tank; (7) and (8), valves for left and right power plants; (9) and (10) left and right engine safety petcocks; (11) reverse valve; (12) fuel pumps. The craft studied lacked the extra auxiliary tank (6), and reports from abroad indicate that the Germans were unable to get this modification into more than a few planes before their defeat.

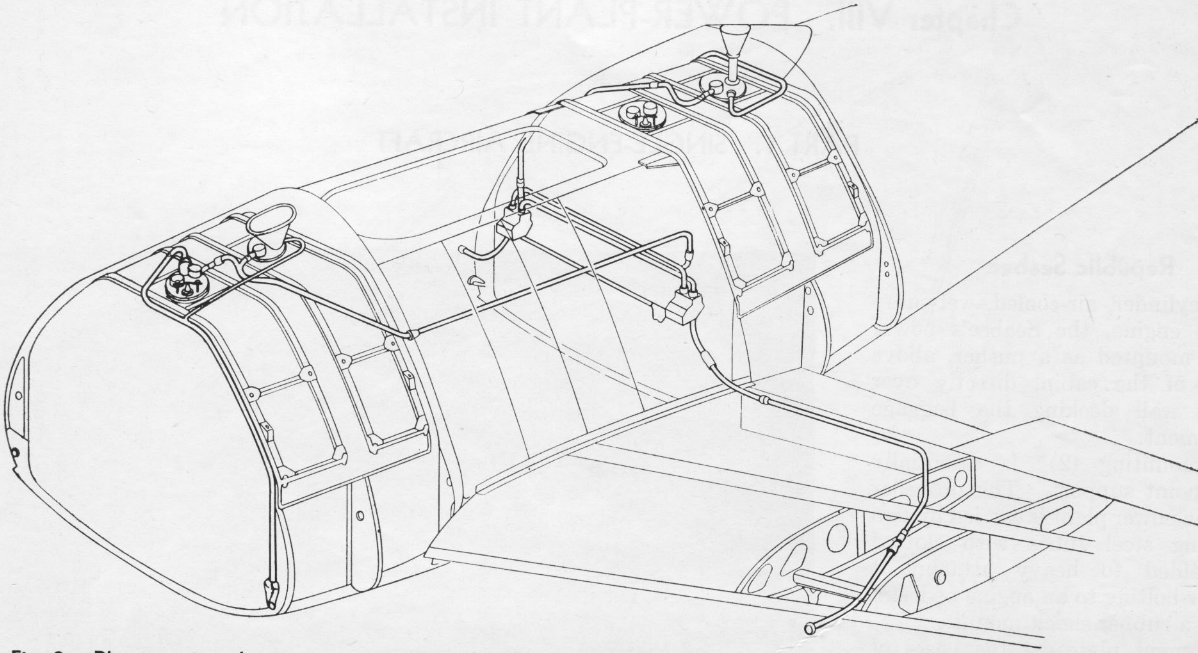


Fig. 2. Phantom view showing two main 238-gal fuel tanks just fore and aft of the cockpit. Each tank is fitted with two booster pumps, and selector valves permit pumping from either tank to either engine, or from the aft to the fore tank. A 53-gal reserve tank can be installed below the cockpit, and the Nazis had plans for an additional tank to go behind the aft unit, with approximately half its capacity.

the latest model and had no such installation. Instead the radio was installed in the space, and the master compass and oxygen bottle a little farther aft. Access to these is through a 17½- by 15¼-in. door held in place by four quick fasteners.

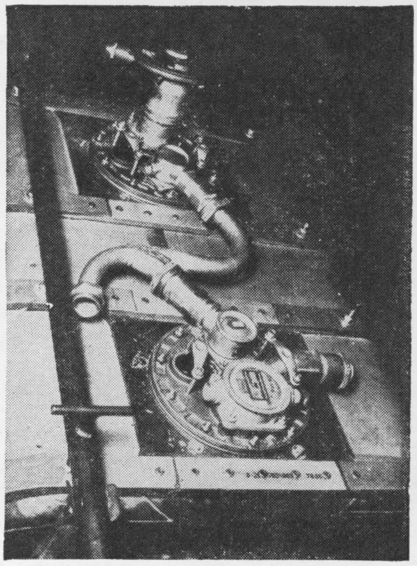


Fig. 3. The top of one of two 238-gal main cells showing the installation of two booster pumps, plywood covering, and supporting straps.

Chapter VIII. POWER-PLANT INSTALLATION

PART 1. SINGLE-ENGINE AIRCRAFT

Republic Seabee

A six-cylinder, air-cooled, wet-sump Franklin engine, the Seabee's power plant is mounted as a pusher, above and aft of the cabin, directly over the fire wall decking the baggage compartment.

The mounting (2)* is essentially a three-point support. The propeller end of the power plant is carried by two converging steel tubes with slotted ends welded to heavy attachment plates for bolting to an engine pedestal carrying a rubber shock mount.

Attachment plates at the bases of the supporting tubes are bolted to .049 pressed-steel hat sections, in turn bolted to the fire wall. Each of these hat sections runs forward and up in a longitudinal plane parallel to the engine thrust line and is picked up by a bolt in another shock-mount pedestal on the crankcase. From this pedestal another hat section on each side runs forward and down and is bolted to the fire wall. Components of the mount are interchangeable for use on either side of the engine.

A ground-adjustable Aeromaster propeller (standard equipment) has laminated maple blades chemically sealed in the ferrule. Blade covering is black Aeroloid plastic sheeting, and monel metal sheathing over the plastic protects the leading edge. An optional Hartzell reversible-pitch prop is pitch-changed by engine oil pressure with manual operation of valve control in the cockpit.

Engine accessories include an electric Autolite starter, generator, regulator, and distributor.

To eliminate fillets and compound curvature of the rear lower cowling, the cowling has been built in two sections as simple wrapped sheets. Each section is straight at the sides and meets the wing at 90 deg. The rear of each section wraps around to meet the other section at the center line of the aircraft, and attachment to the cabin sides is by quick fasteners.

* The numbers in parentheses refer to the illustrations.

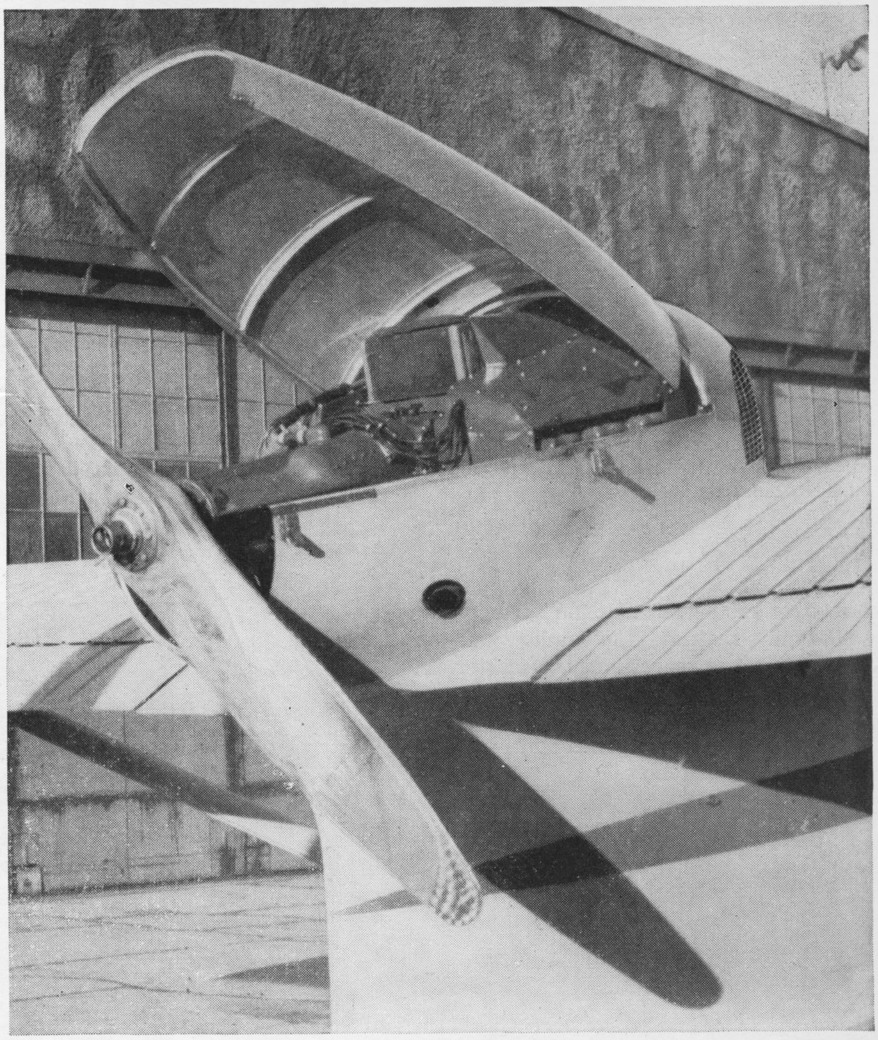


Fig. 1. Engine installation with the top cowling in open position. All cowling (top, rear-side, and forward-side) is removable to afford over-all access to the power plant. Contemplated is removal of the air baffling (seen at the top of the engine to the right of the oil cooler) and its incorporation as an integral part of the top cowling, thus exposing the entire upper part of the engine when the cowling is lifted.

The top cowling (1), from the propeller and forward to the engine fan housing, is a single wrap-around sheet pivoted at the forward end similar to a car hood and is held in the open position by a brace rod on each side.

In closed position, the top cowling is fastened with quick latches to the lower cowling. Forward of the top cowling is another top section fixed in place.

With the top cowling up and with the rear-side cowling removed, the entire engine accessory section is accessible for servicing. Then, by detaching the top cowling by removing a few bolts and then unfastening the forward-side cowling, the entire engine installation is accessible.

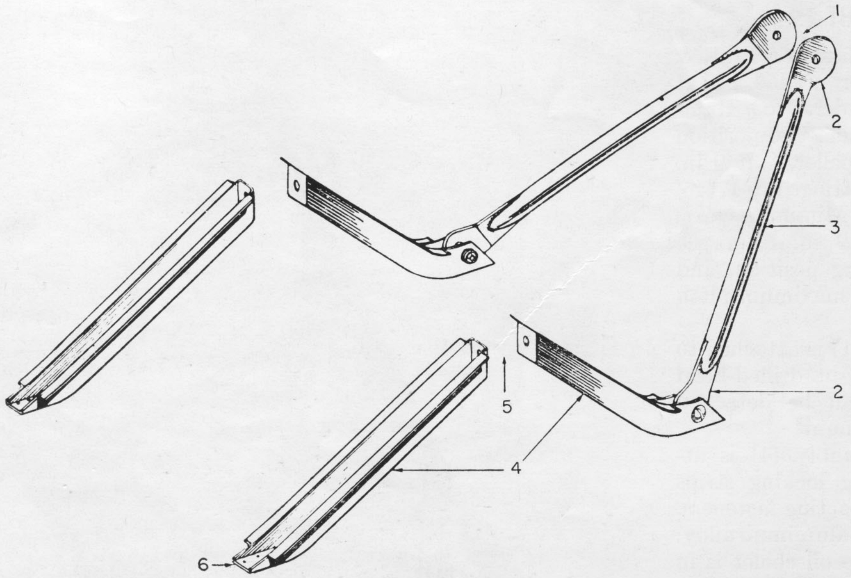


Fig. 2. The simple and sturdy mount for the Seabee's 215-hp Franklin engine: (1) position of the rubber shock mount at the rear (propeller end) of the engine; (2) welded fitting; (3) supporting tube; (4) supporting hat section; (5) position of forward rubber shock mount (on crankcase); (6) forward attachment point to the fire wall and wing cross tie. The mount components are interchangeable for use on either side of the engine.

Zeke 32 (Hamp)

The Zeke 32 is powered by a fourteen-cylinder Nakajima Sakae 21 engine. The engine bore is 5.12 in., and stroke is 5.91. The Sakae 21 has a displacement of 1,700 cu in., diameter of 45 in., and length of 36 in. The weight is approximately 1,175 lb.

Manually operated cowl flaps are provided (1).

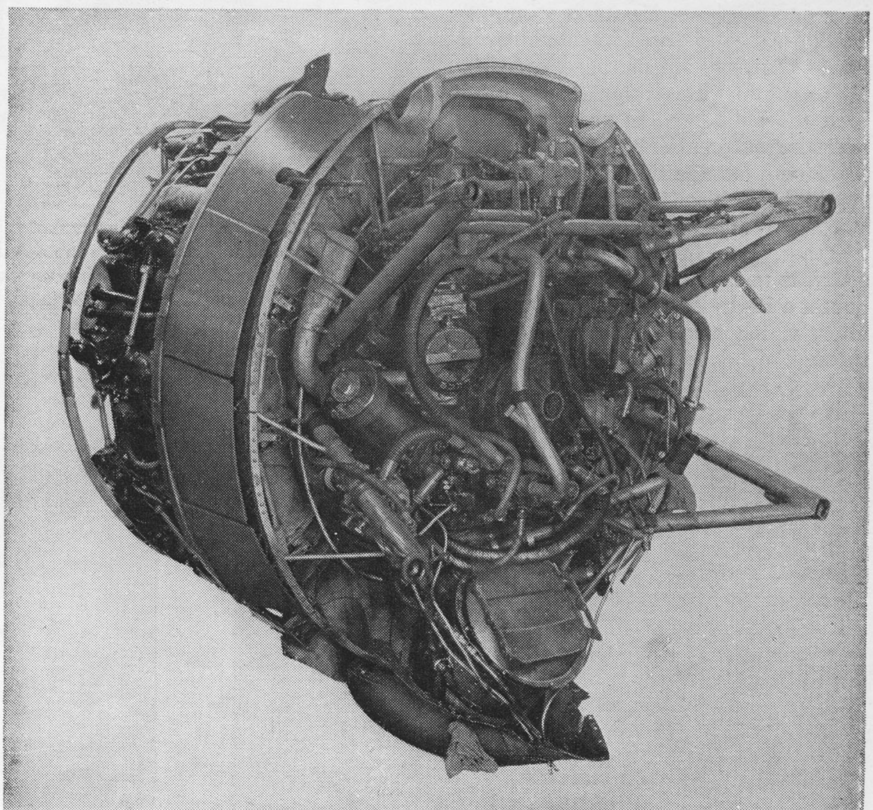


Fig. 1. Three-quarters rear view of a fourteen-cylinder Nakajima Sakae 21 engine powering the Zeke 32. The bore is 5.12 in., stroke, 5.91; displacement 1,700 cu in.; diameter, 45 in.; length, 36 in.; weight, approximately 1,175 lb. The cowl flaps are manually operated.

Fleetwings BT-12

The BT-12 power plant is a Pratt & Whitney Wasp Junior of 450 hp at 2,300 rpm, with direct drive to a Hamilton standard two-blade, two-position controllable pitch propeller, 8 ft 9 in. in diameter. Pitch settings are 17°45′ high and 13°30′ low. Minimum clearance of propeller is 9 in. from the ground in level landing position, and 1 in. from the cowl at maximum pitch setting.

The engine mount (1) is attached to the fuselage by four ½-in. drilled-head bolts. The engine can be detached with or without the mount.

The ring cowl assembly (4) is attached by flush-fitting locking strips and Shakeproof quick-acting fasteners. The material is formed aluminum alloy. A built-in duct for the oil cooler is in the lower section of the ring cowl (2). An internal duct right beside it feeds the carburetor air scoop, while above in the upper section is a blast tube for cooling the accessory compartment.

A noteworthy feature of this installation is the carburetor-air mixing chamber, of Fleetwings design, which is a one-piece aluminum casting (3). The lower scoop draws in cold air from inside the front lip of the cowl, while the upper inlet draws warm air from behind the cylinders. A shutter in this aperture automatically by-passes this air stream outside the opening when it is not being used by the carburetor. Both cold- and warm-air shutters work together, one being open when the other is closed. This chamber also houses a 12- by 12- by 2-in. flat-type air filter, which may be removed readily through the door in the rear.

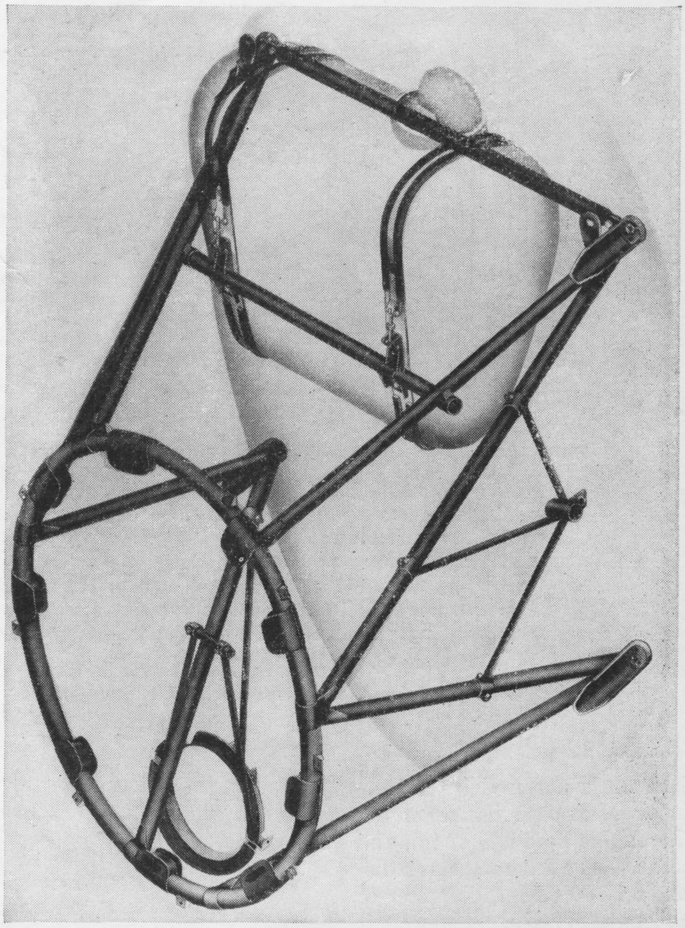


Fig. 1. The engine mount is attached to the fuselage by four ½-in. drilled-head bolts. The detail drawing shows the position of conical aligning studs for lining up the boltholes when attaching the mount. The engine can be detached with or without the mount.

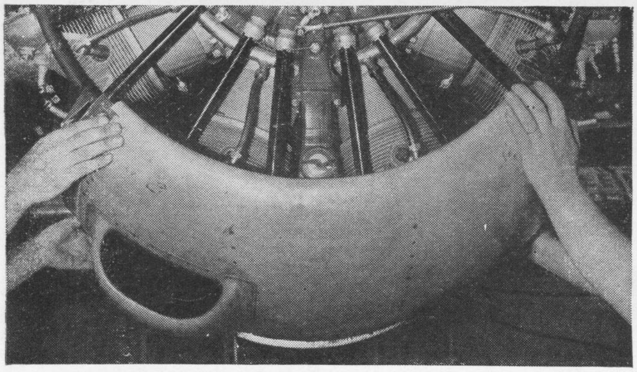


Fig. 2. The lower section of the ring cowl illustrating a built-in duct for the oil cooler.

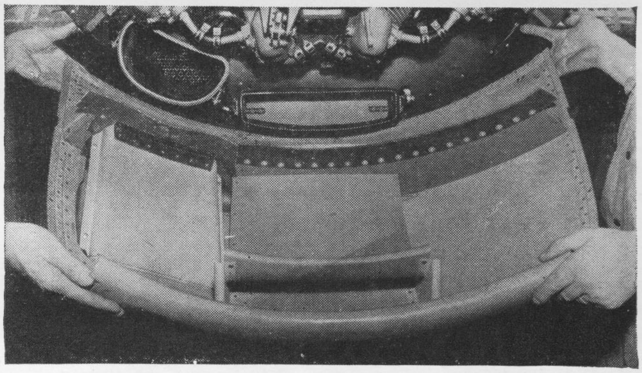


Fig. 3. Carburetor-air mixing chamber.

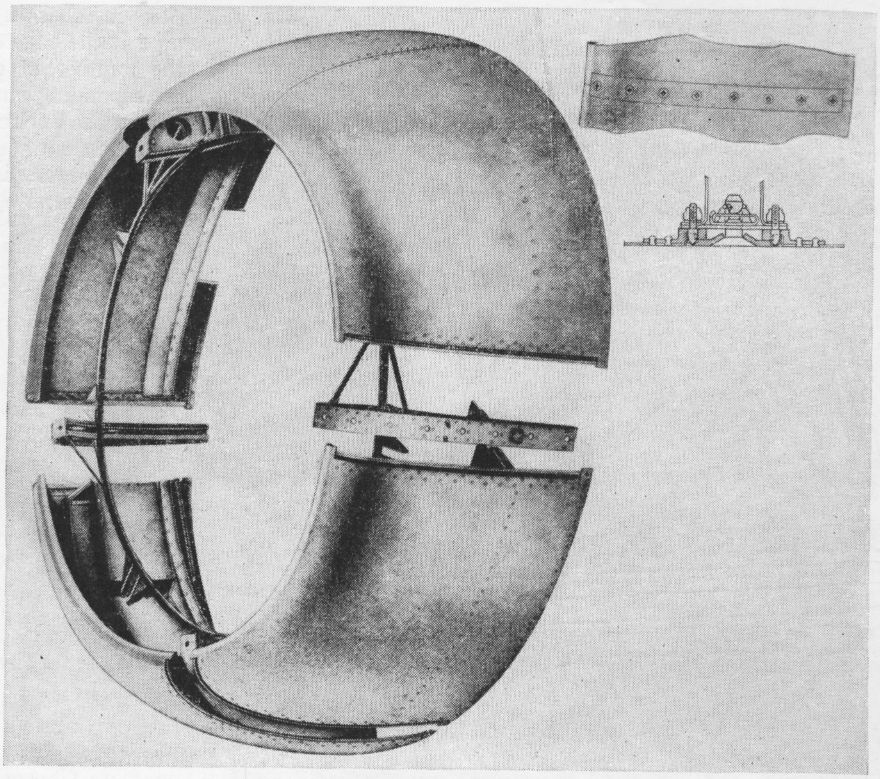


Fig. 4. Ring cowl assembly.

Focke-Wulfe FW-190

The engine-mount ring of the FW-190 is attached to the engine mount at four points (1), the loads being distributed to the four corners of the fuselage and to the bottom of the front spar at the center line.

Throttle control linkage leads from the left to the right side of the aircraft before going forward through the engine-mount ring. Pulling the throttle lever back into the rear slot kills the engine; pushing forward and across the quadrant gives a double boost for short periods. A thumb switch on the end of the throttle handle controls the propeller pitch electrically.

Three adjustable air-outlet flaps, mounted in doors hinged at the bottom, are set on each side of the engine cowling (2). To operate them, a screw-and-nut mechanism is attached to the forward side of the fire wall and is connected to each side door by tubes. The latter are connected to linkage on the doors by levers and bell cranks so arranged that they do not have to be removed or adjusted when the doors are opened.

All oil lines going through to the fuselage are attached to permanent fit-

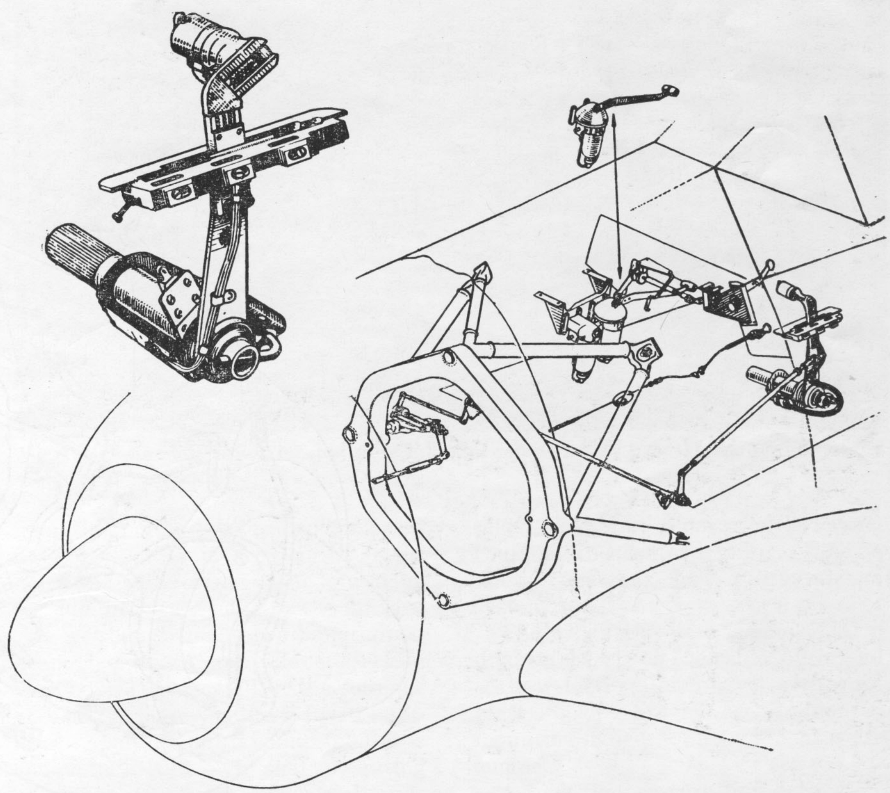


Fig. 1. The engine-mount ring and the throttle control linkage. The detail at the upper left depicts the throttle itself.

tings installed in the fire wall (3). A tape at the edge of the fuselage carries the number of each connection; the corresponding number is on the line itself on the encircling tape just behind the union nut.

The oil cooler is set behing the armor plate in the nose of the engine cowling (4).

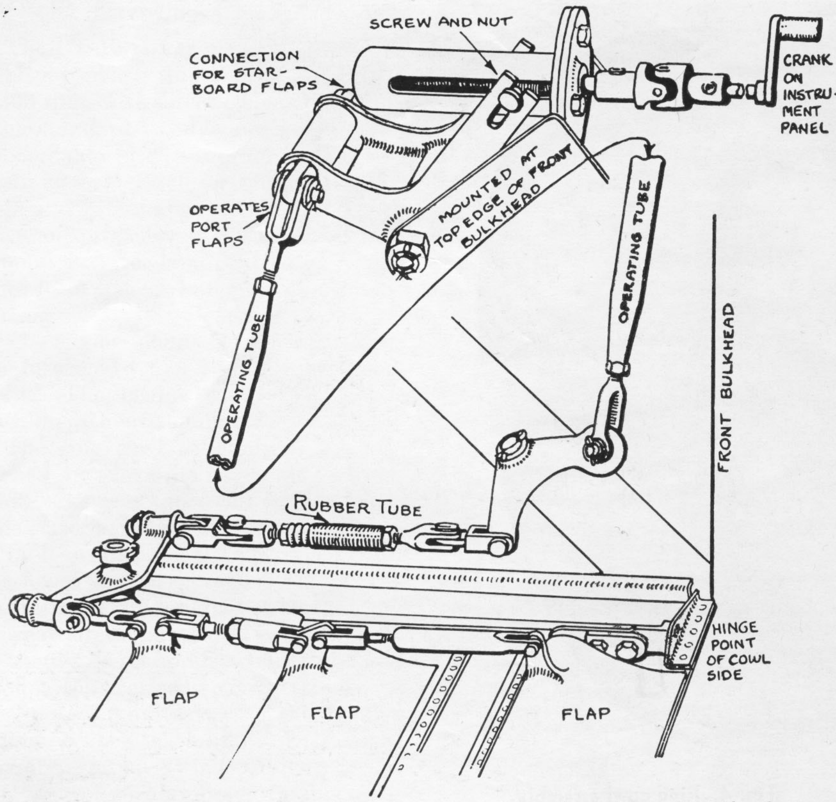


Fig. 2. Three adjustable air-outlet flaps, mounted in doors hinged at the bottom.

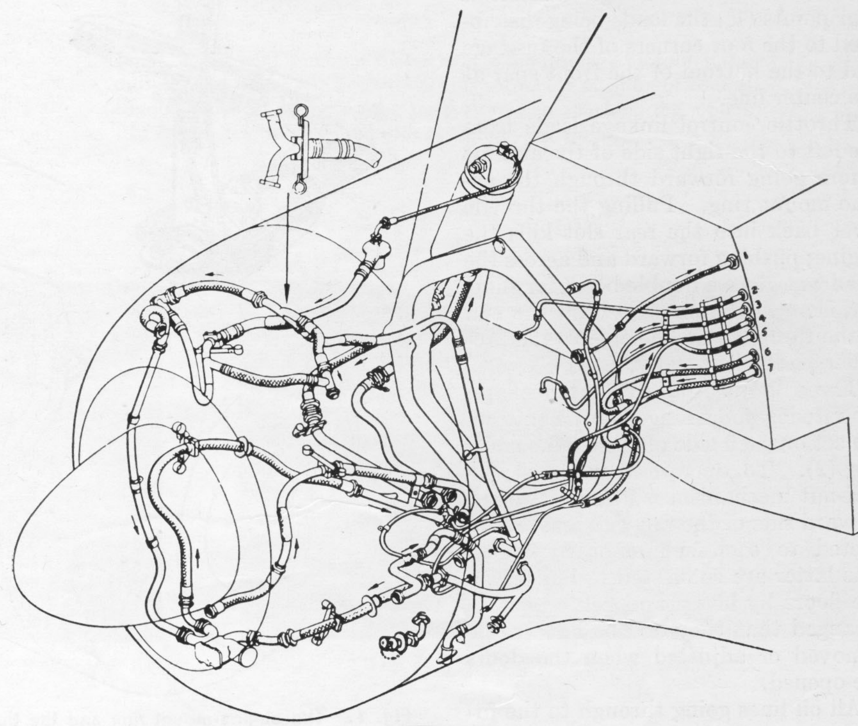


Fig. 3. Group assembly showing all oil lines for the power plant.

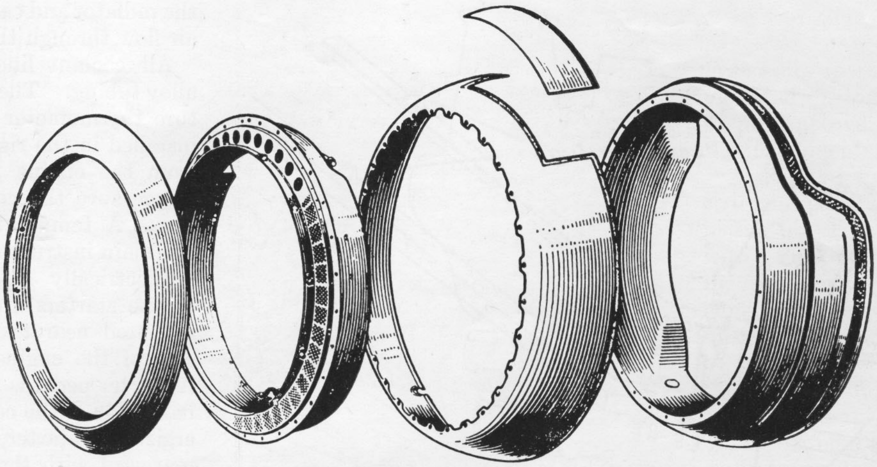


Fig. 4. The oil cooler of the FW-190 is set behind armor plate in the nose of the engine cowling. The exploded view shows (left to right) armor plate, oil cooler, armor plate, and cowling.

Bell P-39 Airacobra

The cowling is attached to the P-39's fuselage at four main points: the gun compartment forward of the cockpit; the engine compartment; the Prestone and oil radiator compartments on the underside of the wing center section; and the oil tank compartment in the aft fuselage behind the engine accessories bay.

The cowlings are formed aluminum sheet ranging from .051 gauge at the gun, Prestone, and oil radiator compartments to .032 gauge at the engine and oil tank compartments. Access doors, integral parts of the cowling, are located in the engine compartment for access to the Prestone expansion tank, and in the radiator compartments for access to the Prestone drain. A section of the cowling directly over the rear of the engine contains the carburetor air-intake scoop. Another section, directly over the engine, houses the aft cabin Plexiglas enclosure.

The gun compartment and cowl sections are attached to removable channel-shaped formers and bulkheads with flush-type fasteners. The engine compartment sections are strengthened with channel stiffeners, and the radiator compartment cowls by several permanently riveted interlocking stiffeners.

Located aft of the cockpit, directly over the rear portion of the wing center section, the Allison-type V1710 engine (1) is mounted on four "Fabreeka" pads inserted between the engine

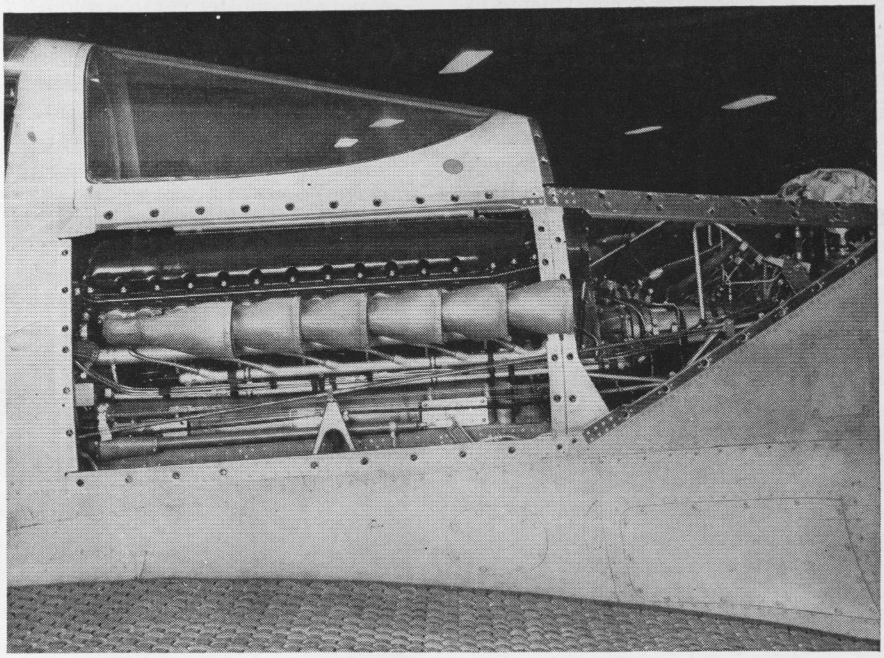


Fig. 1. Engine installation located aft of the pilot cabin directly over the rear portion of the wing center section.

mounting points and the airplane beam fittings (2). It is secured by eight bolts and nuts arranged in four pairs through fittings riveted to the inboard side web beneath the top longitudinal beam flange. A propeller reduction gear box (3) is located in the fuselage nose and is bolted to the forward bulkhead. The gearbox is connected to the engine by a 10-ft drive shaft operating at crankshaft speed. This shaft runs through the beam fuselage under the pilot's seat and consists of a flanged coupling and center bearing. The reduction gearbox has a separate oil system.

The exhaust system is comprised of dual stacks, six on each side, of formed, seam-welded stainless steel with sandblast finish. Stacks are welded to mounting flanges for attachment to the engine.

A high-temperature liquid Prestone cooling system (4) is provided for the

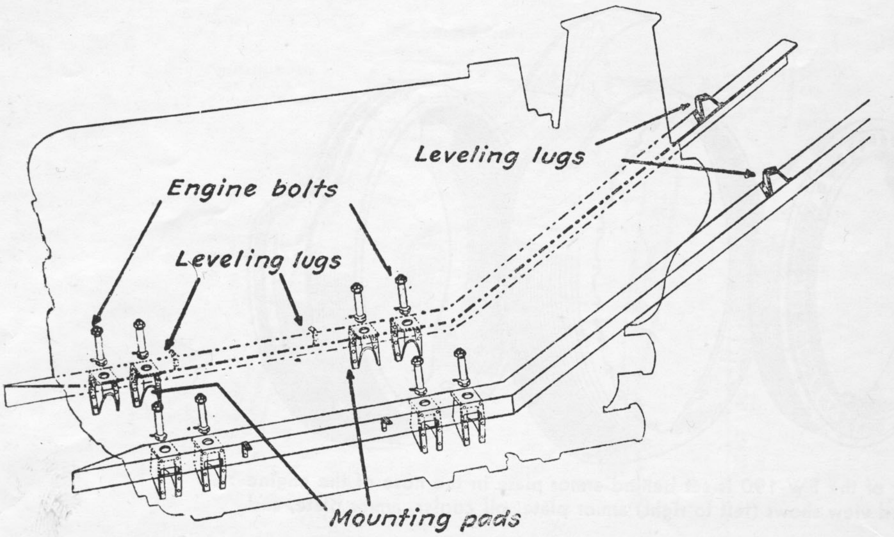


Fig. 2. The engine is fastened to the forward fuselage across longitudinal beams and tied down by eight bolts in four pairs and mounted on "Fabreeka" pads.

engine. The Prestone radiator is of the cartridge core type, constructed in two sections and assembled as a single unit in a radiator mounting cradle. The assembly is mounted on four flexible vibration-insulating units below the engine, between the longitudinal beams aft of the wing carry-through rear beam. Coolant is carried in lines from the outlet on the top forward end of each cylinder head to the radiator.

Coolant enters the radiator through a compound inlet on each side of the radiator top and flows downward and rearward, returning to the coolant circulating pump inlet collector (5).

The Prestone expansion tank is so arranged that when filled to the level of the filler neck, when the plane is in its normal rest position, it will contain the proper amount of coolant and of expansion space. The system is vented automatically to prevent air locks, allow the expansion of coolant, relieve coolant pressure beyond 3 lb, and permit reentrance of air after the coolant temperature drops. The automatic relief and sniffle valves are included in the cooling system filler unit located on top of the tank.

The coolant circulation pump is of the centrifugal type and forms a part of the engine. It is mounted on the bottom of the engine accessory housing on the rear left side of the engine.

Two separate air ducts are located on either side of the fuselage at the wing center section leading edge. The ducts run rearward and converge directly in front of, and connect to, the coolant radiator with an airtight seal.

A radiator shutter control is located on the cockpit floor just below and forward of the oil shutter control consisting of a gearbox with a small handcrank which turns clockwise to close and counterclockwise to open.

A flexible shaft extends aft, inside the fuselage beam, to a screw actuating a trunnion on the shutter-operating arm. The shutter is located at the air exit of the radiator and can completely restrict air flow through the radiator.

All coolant lines are of aluminum alloy tubing. The coolant temperature thermometer well is permanently installed in the right-hand coolant line from the engine top to the radiator to measure the coolant OUT temperature. A temperature indicator is on the main instrument panel.

Electrically operated, inertia-type engine starters are used on the P-39, mounted near the bottom right-hand side of the engine accessory housing. A starter pedal is located on the right-hand side of the cockpit floor. To energize the starter, the pedal is pressed rearward with the heel. It is held in this position until the starter is energized sufficiently to rotate the engine, and then the pedal is depressed forward with the toe to engage the starter with the engine.

A handcrank is provided and installed in a compartment within the right wing trailing edge. The handcrank extension shaft with sleeve is permanently installed and has a bronze bearing support within the fuselage. It is accessible through a hinged door located on the right-hand side of the fuselage near the wing T.E.

On some models a mechanism is included for lifting the starter brushes to

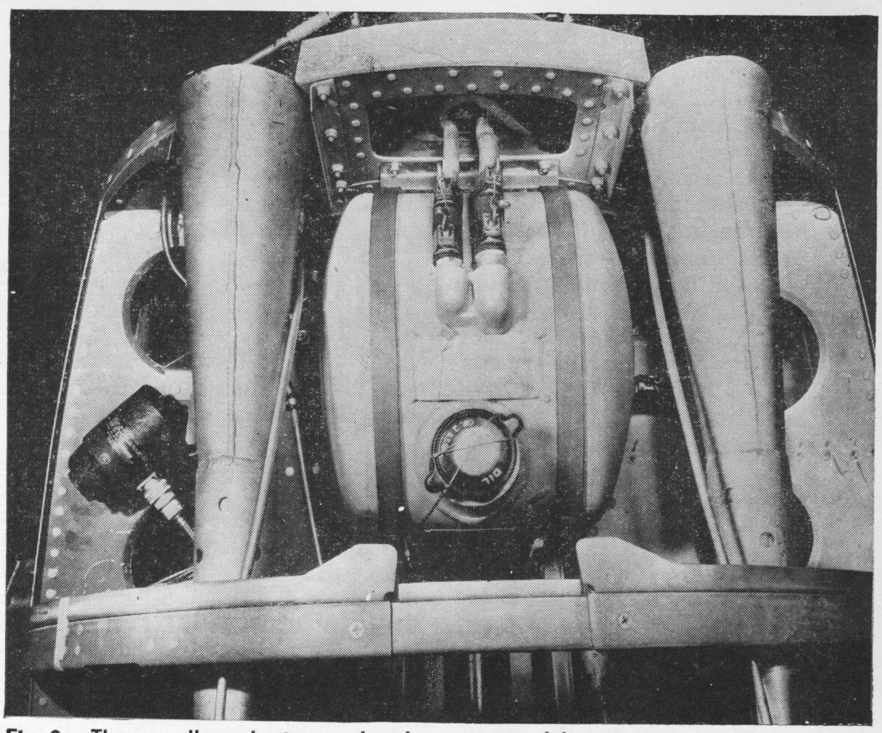


Fig. 3. The propeller reduction gearbox has a separate lubrication system with an oil tank mounted just behind the gearbox between .50-caliber machine guns.

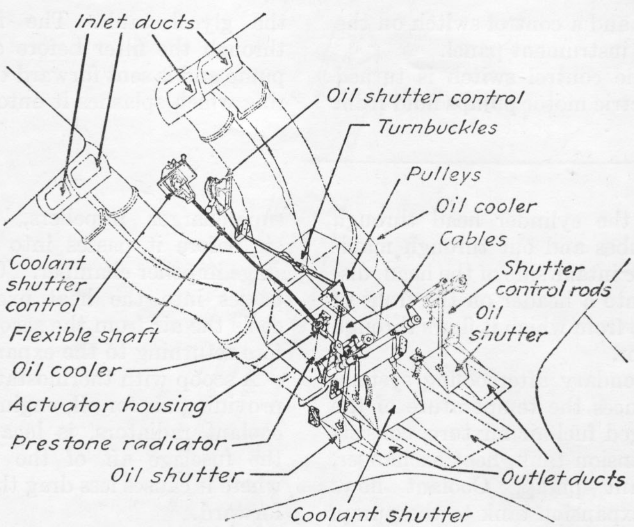


Fig. 4. The high-temperature Prestone cooling system for the Allison engine.

prevent generation of a charge while the starter is being energized manually. A lever, located in an access door next to the starter door, is operated when the handcrank is being used.

When the starter is engaged and the engine started, the lever is operated to return the brushes to their normal position. There is an electric plug located in the left-hand wing T.E. fillet which may be used in conjunction with an outside battery for cold-weather starting. The plug is connected to the electric inertia starter mechanism.

An engine-driven generator is mounted on the engine accessory housing to the rear. The generator control panel is mounted on vibration-absorbing units and is installed in a structural enclosure within the left side of the fuselage.

A generator relay is operated by a toggle switch on the main electric control panel.

A battery-operated booster coil unit is mounted in a shielded box on the right-hand inclined deck aft of the engine within the fuselage. The circuit is connected so that the coil is energized when the pedal starter switch is depressed forward to the engaged position, bringing the solenoid-operated starter meshing mechanism into operation.

Current is carried from the booster coil to the right-hand distributor by a high-tension lead. The solenoid-operated starter meshing mechanism is mounted on the starter.

A three-focus electric retractable landing light assembly is installed flush with the lower surface of the left-hand outer wing panel. It can be lowered and stopped at any intermediate position or retracted by means of an electric motor controlled by a switch on the main control panel. A cutoff switch is provided on the unit which automatically stops the motor when the light reaches its maximum extended or retracted position.

Mounted on the rear of the engine, a vacuum pump is used for forming a vacuum essential for operation of certain instruments. The pump includes a suction line from the instrument panel and an exhaust line to the Pesco oil separator. A relief valve is mounted on top of the vacuum pump to prevent overexertion of suction on the instruments.

A suction gauge mounted on the instrument panel records vacuum suction in the lines. An air filter is included with the vacuum system and is mounted on the left-hand forward inclined deck beneath the gun compartment cowling. This unit is maintained to remove any minute particles from the air that might injure the mechanism of the instrument.

Deicing equipment includes a glycol spray to prevent formation of ice on the windshield, and a propeller blade deicing installation. Both units are supplied from a single glycol tank mounted in the gun compartment of the forward fuselage. The windshield deicing equipment consists of a hand pump located on the right-hand instrument panel, a nozzle assembly on the windshield, and a deicing rheostat, also on the right-hand instrument panel.

When the pump is operated, a glycol fluid is drawn from the bottom of the glycol tank and is pumped to the windshield nozzle assembly located just above the windshield armor plate. The nozzle is curved to the windshield contour and is profusely punctured to facilitate several streams of fluid ejected upward on the glass.

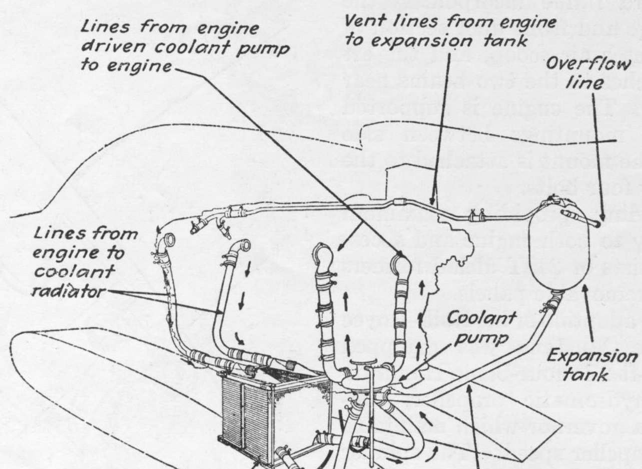


Fig. 5. Flow diagram showing the movement of the engine coolant in P-39 design.

Propeller deicing equipment includes an electric driven Adel pump with a filter, a nozzle assembly, a propeller slinger ring (included with the propeller assembly), and a control switch on the right-hand instrument panel.

When the control switch is turned on, the electric motor pumps fluid from the glycol tank. The fluid passes through the filter before entering the pump and is sent forward to the slinger ring which splashes it onto the blades.

North American P-51

This P-51 model is powered by a twelve-cylinder Packard-built Rolls-Royce 1,500-hp, V-1650, liquid-cooled engine having an aftercooler to reduce the charge temperature.

The induction system employs a two-speed, two-stage supercharger with a low gear ratio of 6.391:1, and high gear ratio of 8.095:1. The pilot may select cold rammed air; cold unrammed filtered air; or unrammed hot air, as necessary.

The Bendix-Stromberg double-throated, injection-type, updraft carburetor is fitted with a double-diaphragm acceleration pump, automatic mixture control, fuel-pressure regulator, fuel-control unit, and throttle.

An automatic manifold pressure regulator limits the maximum boost when below full throttle and maintains a predetermined pressure for any given position of the throttle lever.

Ignition is provided by two magnetos of the rotating magnet type, the right-hand one being connected to a booster coil which supplies high-tension current when starting.

The engine mount (2) consists of two Y-shaped 24ST box beams stiffened by built-up cross members of 24ST alclad. The forward frame incorporates the leading edge and front duct section of the carburetor air scoop, and the aft frame attaches to the two beams near the center. The engine is supported on rubber mountings between side beams. The mount is attached to the fire wall by four bolts.

The cowling, providing maximum accessibility to both engine and accessories, consists of 24ST alclad formers and seven removable panels.

With the adoption of the Rolls-Royce engine, the Mustang was equipped with an 11-ft 2-in four-blade Hamilton standard hydromatic propeller, controlled by a governor which maintains selected propeller speed. The spinner is a streamlined spun shell of aluminum alloy.

The engine cooling system (1) utilizes a centrifugal pump which delivers coolant into a jacket on the lower exhaust side of each cylinder block, whence it passes to the cylinder head through transfer tubes and out through manifolds on the intake side of the head, discharging into a header on the front of the engine, from which it flows through the radiator.

The secondary aftercooling system, which reduces the temperature of the supercharged fuel-air mixture, consists of an expansion tank, heat exchanger, and coolant pump. Coolant flows from the expansion tank to the pump, through the radiator and supercharger case, and through a jacket between the supercharger impellers, cooling the air before it passes into the second-stage impeller chamber. Coolant then passes into the heat exchanger and cools the air from the second stage before returning to the expansion tank.

A scoop with thermostatic exit flaps, providing air for oil, engine, and aftercoolant radiators, is located beneath the fuselage aft of the cockpit (3), where it causes less drag than if farther forward.

At high speed, jet action from the heated air compensates to a large de-

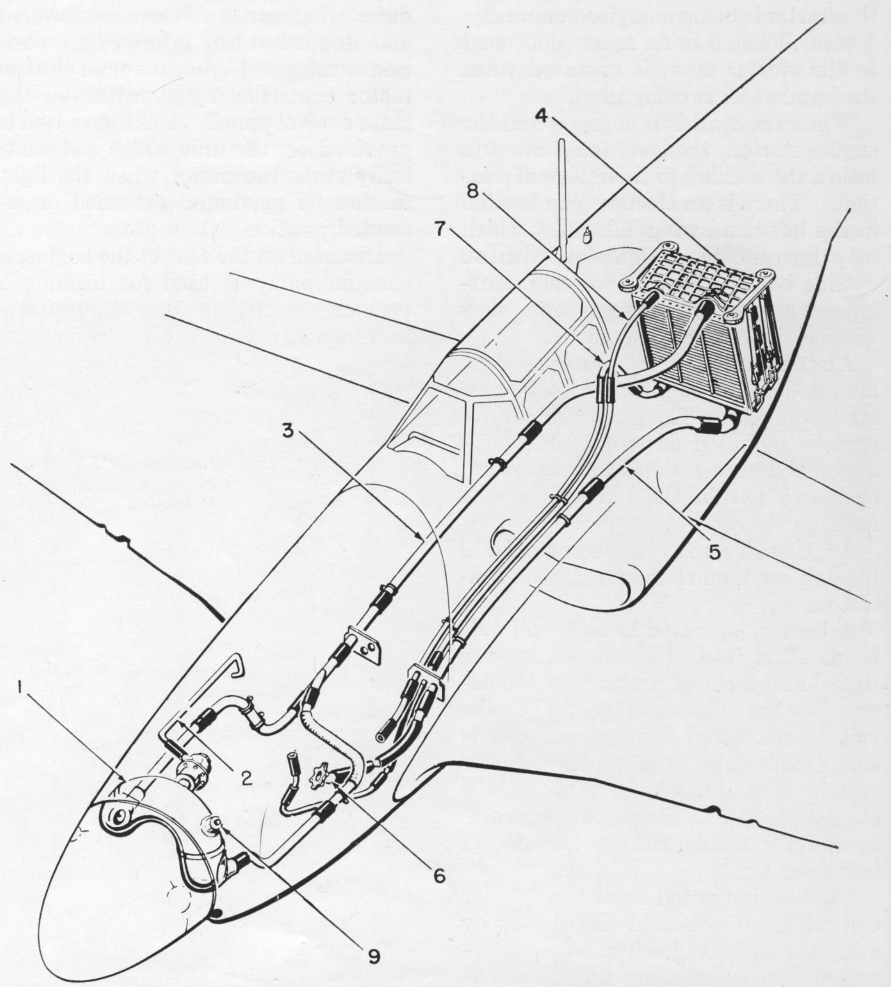


Fig. 1. Engine coolant system. Here (1) is a coolant header tank vented at (2) which connects through pipe (3) to radiator (4) returning liquid by pipe (5) to pump (6). The supercharger cooler is supplied by (7) and (8). The system is filled at plug (9).

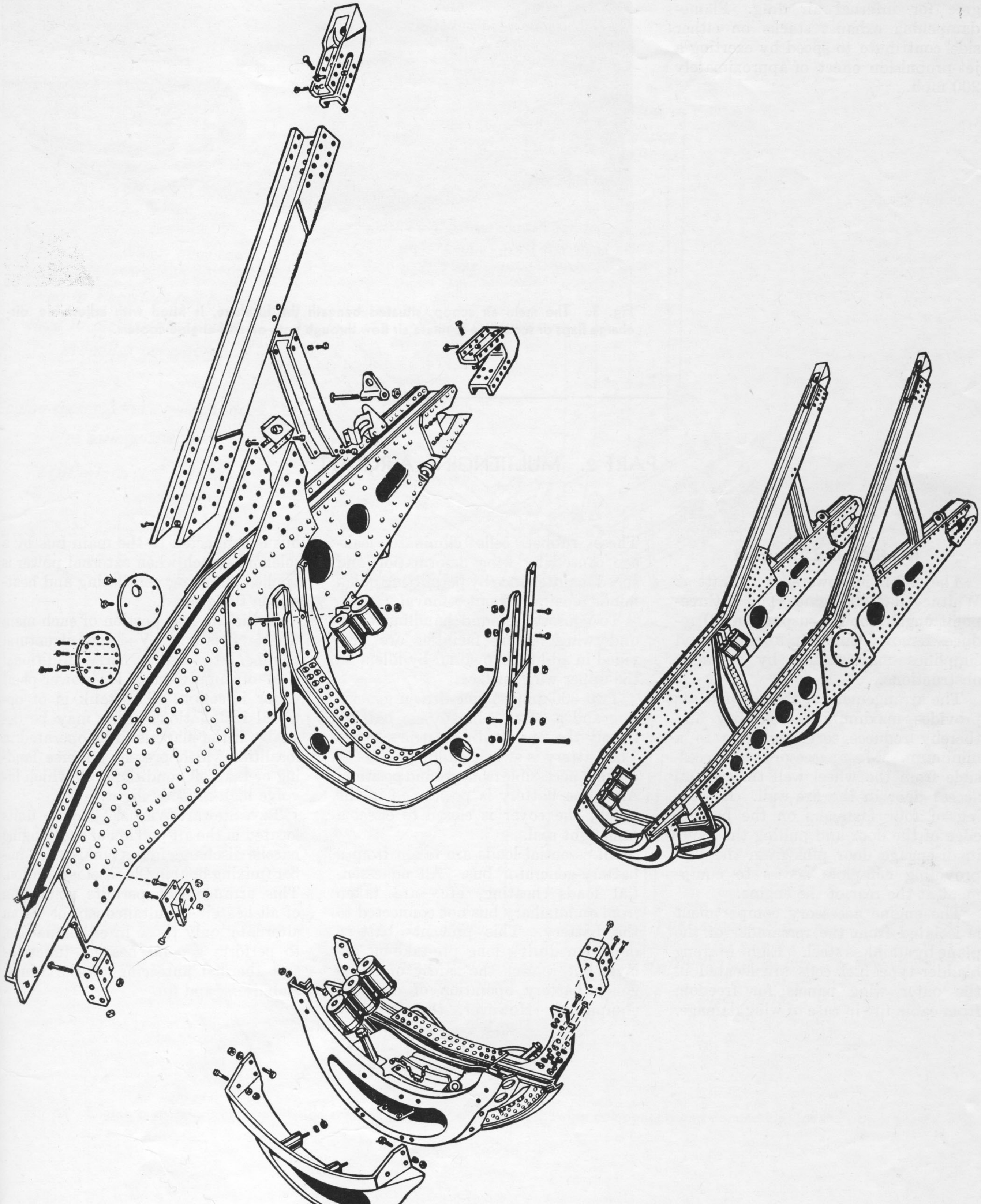


Fig. 2. Structural design details of the engine-mount frame of the P-51.

gree for internal air drag. Flame-dampening exhaust stacks on either side contribute to speed by exerting a jet-propulsion effect of approximately 200 mph.

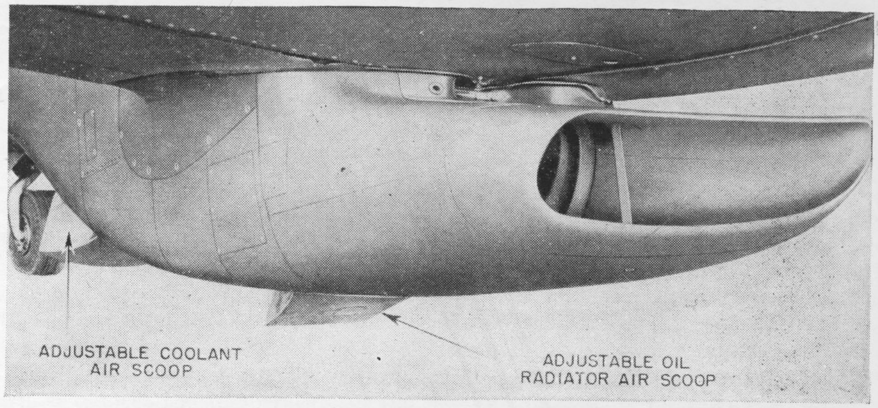


Fig. 3. The main air scoop, situated beneath the fuselage, is fitted with adjustable discharge flaps or scoops to regulate air flow through both oil and engine coolers.

PART 2. MULTIENGINE AIRCRAFT

Martin 2-0-2 Transport

The 2-0-2 is powered by Pratt & Whitney R-2800 engines (1). A three-point engine mount suspension (2) reduces removal time to a minimum and simplifies maintenance by reducing obstructions.

The arrangement of the components provides maximum accessibility and thereby reduces servicing time to a minimum. Most accessories are accessible from the wheel well through an access door in the fire wall. Loosening of four fasteners on the bottom edge of the door and pulling the panel in disengage door pins from the top, providing complete access to equipment at the rear of the engine.

The engine accessory compartment is isolated from the remainder of the plane by stainless steel. Eight Mareng bladder-type fuel cells are located in the outer wing panels for freedom from cabin fire in case of wing damage. These rubber cells eliminate leakage caused by wing deformation and speed maintenance by permitting quick minor repairs without removal.

To conserve ground handling time, underwing fueling facilities are provided in addition to stand-by fillers on the upper wing surface.

Two 300-amp engine-driven generators and a 34-amp-hr storage battery supply the 24-volt d-c electric system. The battery is swung on hinge arms to make it accessible from ground position. After the battery is positioned in the hatch, the cover is closed to effect a fumetight seal.

All essential loads are taken from a battery-generator bus. All nonessential loads—heating, etc.—are taken from an auxiliary bus not connected to the battery. This prevents battery depletion during long pre-take-off delays, but retains the safety of emergency battery operation of essential equipment. However, the auxiliary bus is connected to the main bus by a solenoid switch when external power is applied, allowing ventilating and heating on the ground.

In the top rear portion of each main wheel well is a deep V-shaped structural member stressed to carry additional load of supply tank for power-plant water injection. The tank is of optional installation, which may be desirable if the plane is to be operated in localities which present adverse landing or take-off conditions, or which involve high-altitude flight.

Two Stewart-Warner gasoline units located in the aft portion of each engine nacelle discharge into a common chamber (mixing box) in the fuselage section. This arrangement permits utilization of all heaters simultaneously or, as an alternate, only those in either nacelle, to perform general heating functions and thermal anti-icing of the wings, stabilizers, and fin.

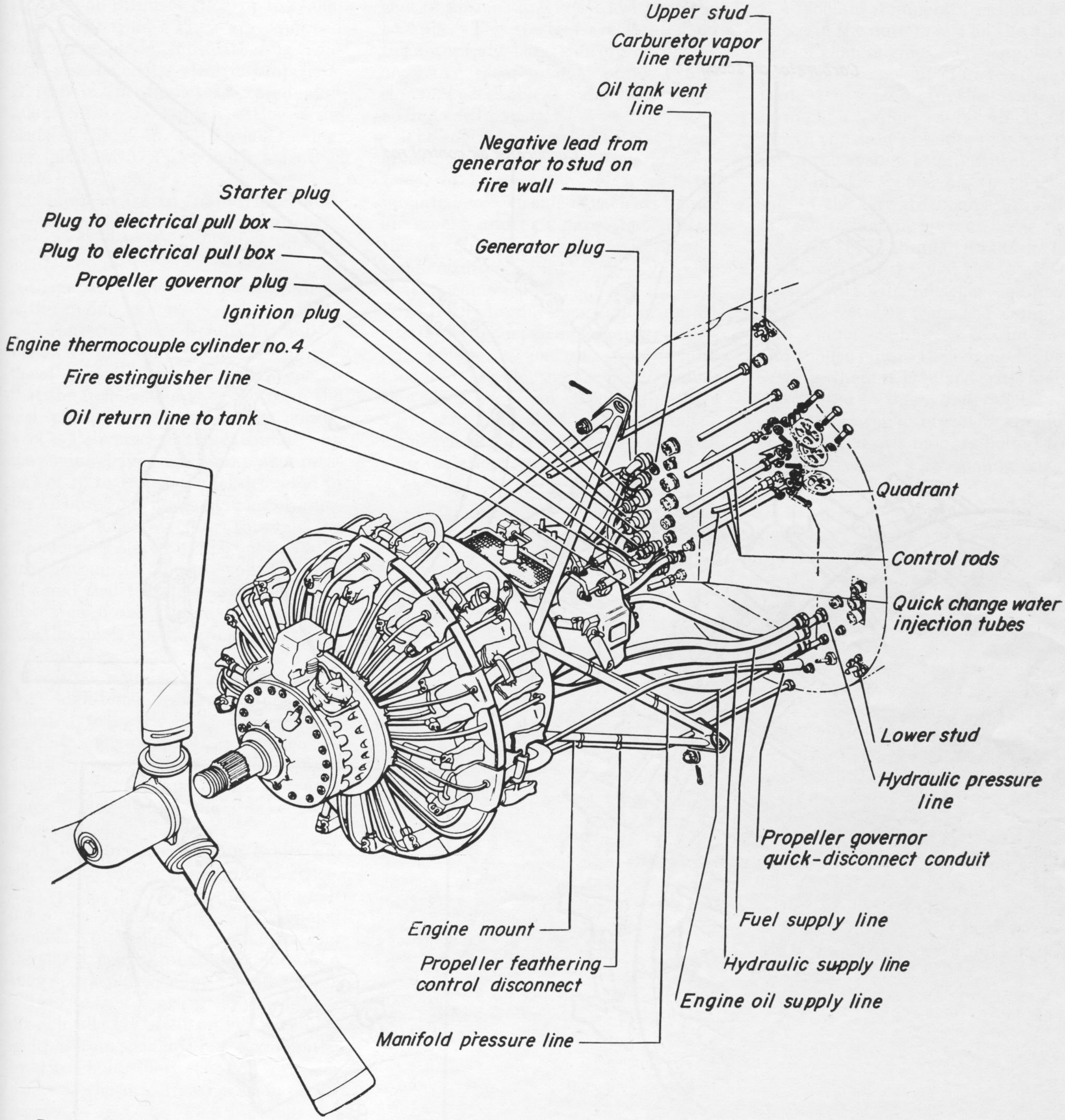


Fig. 1. Engine preparatory unit installation drawing for the Martin 2-0-2 showing components and connections for the power plant.

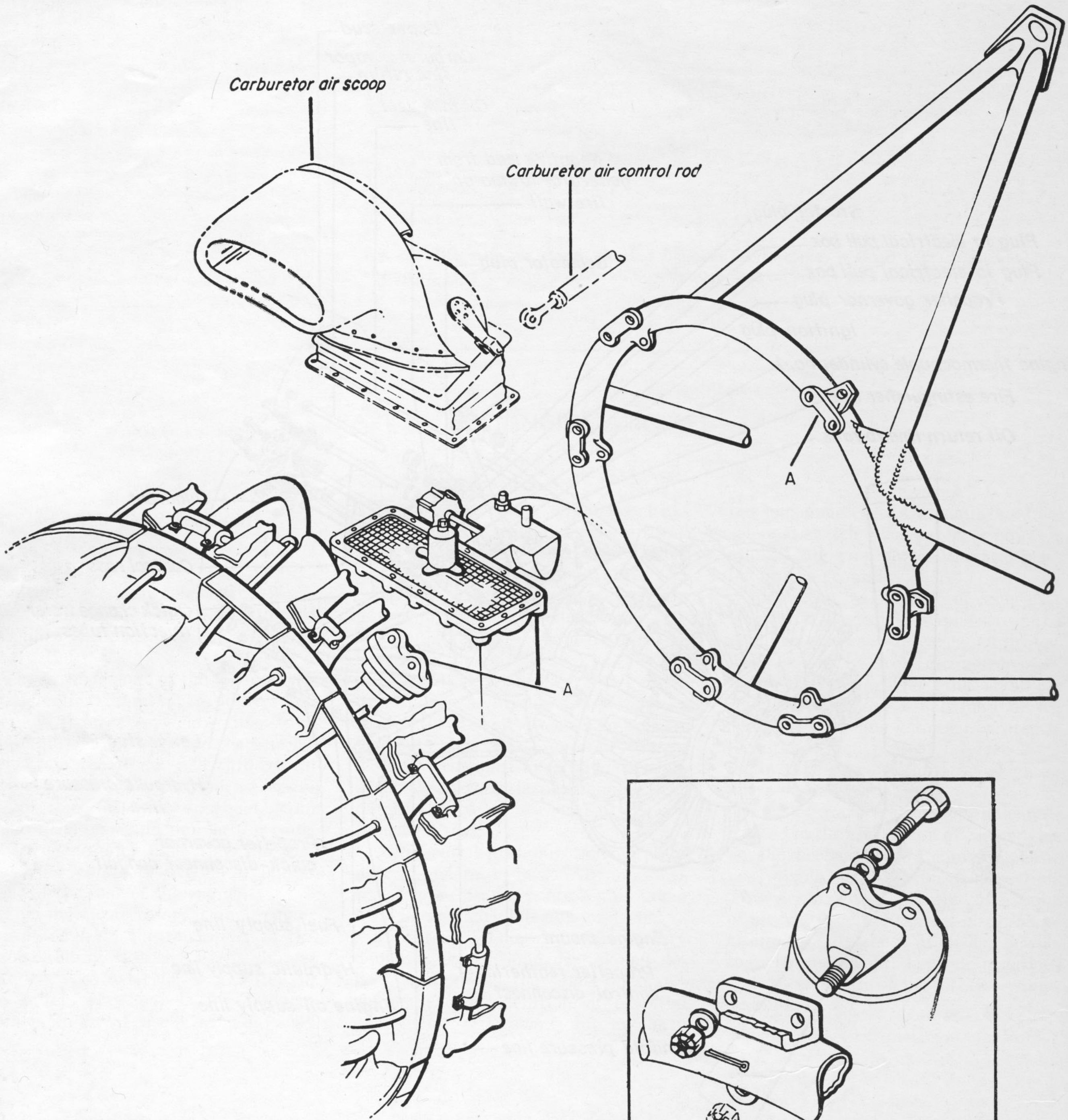


Fig. 2. Engine mount of the Martin 2-0-2 showing fitting attachment details *A* in the inset at the lower right.

Lockheed P-38

The P-38 is equipped with turbo-supercharged twelve-cylinder liquid-cooled V-1710 Allisons with a military and take-off rating of 1.520 hp to 27,000 ft at 3,000 rpm. They are equipped with three-blade full-feathering constant-speed Curtiss electric propellers, 11 ft 6 in. in diameter, geared at a 2.00:1 ratio. Low-pitch setting of the blade at the 42-in. station is 22.7 deg; high-pitch is 57.7 deg with a feather angle of 87.5 deg.

Clearances are: to ground, level landing, approximately 16 in.; to fuselage, 9½ in.; to wing leading edge, approximately 60 in.

Diagonal tubular members are used in the engine mounts (1).

Carburetors are Bendix-Stromberg PD-12K7 and differ from the conventional vented float chamber type in that the fuel system is closed from the fuel pump to the discharge nozzle. Fuel is delivered to the carburetor by the engine-driven fuel pump at a pressure of 16 to 18 psi. Fuel delivered to the carburetor is metered in accordance with the mass air flow through the throat as registered by the venturi tube and automatic mixture-control unit. Metered fuel then passes through the discharge nozzle where it is sprayed into the air stream entering the internal supercharger.

Ignition voltage is provided by a dual, high-tension magneto and is distributed to spark plugs through two separate engine-driven, high-tension distributors. Magneto timing is fixed and fires the exhaust bank of spark plugs 6 deg before the intake bank plugs.

All high-tension ignition cables are shielded to prevent radio interference. Two spark plugs are used for each cylinder, the exhaust plugs being cooled by a blast of cooling air conducted from the slip stream through two aluminum alloy spark-plug cooling manifolds.

The magnetos are pressurized Bendix-Scintilla DFLN-6, providing double ignition from a single unit and mounted by two bolts between the cylinder banks at the upper rear section of the engines.

Throttle, mixture, and propeller governor controls are levers mounted in the side control stand at the pilot's left in the cockpit. The starting system is composed of a start switch with three positions—off, right hand, and left hand; an engage switch with three positions—off, right hand, and left hand; two starters, with manual crank extensions; and two booster coils.

Start and engage switches are located atop the main switch box adjacent to the master ignition switch in the cockpit. The starters are located on the lower right-hand side of each engine accessory case; manual crank extensions are accessible through doors in the engine cowl panels.

The engines are cooled with ethylene glycol, Spe. AN-E-2, by separate systems, each consisting of a radiator mounted on each side of each aft boom; air scoops and exit flaps that control the air flow through the radiators; a temperature-reactant four-way valve that automatically controls the exit flaps by hydraulic operation of an actuating cylinder; an engine-driven coolant pump; a coolant supply tank mounted astride the propeller reduction gear case; an absolute-pressure valve that vents the supply tank to the atmosphere and compensates for pressure variations.

Five drain cocks are installed at low points of the system, and a bleed cock is at the highest point. A T restrictor between the cylinder banks prevents excessive coolant from by-passing.

A coolant temperature bulb is inserted in the outlet tube on the inboard side of each engine. The supply tank provides for coolant storage space and vents the system to the atmosphere through a sniffle valve which maintains a constant absolute pressure of 23 psi in the system at all altitudes.

Air-intake scoops on the outboard side of the forward booms provide air for the induction system. Air passes from the scoop through an intake filter, if desired, and through the intake duct to the turbosupercharger compressor. It is discharged from the compressor into a duct leading to the intercooler and thence enters the engine induction system where it is mixed with fuel and distributed to the cylinders.

Air Research intercoolers are mounted on four Lord mounts bolted to the engine trusses. The cooling air flow

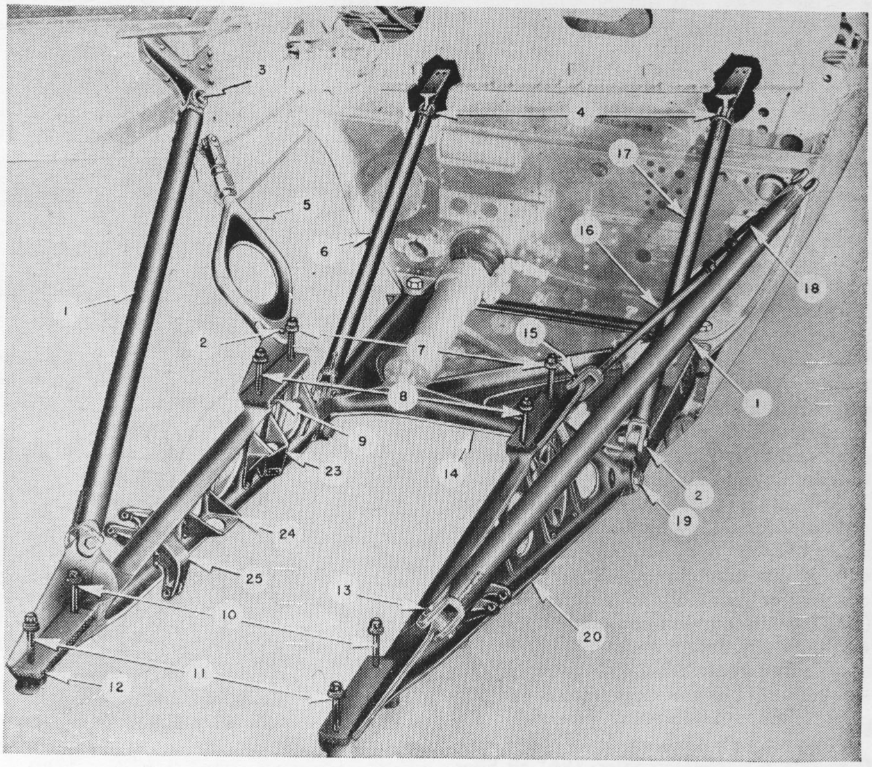


Fig. 1. Engine-mount and support assembly: (1) diagonal tubular members; (2) yoke attaching bolt; (3) upper diagonal bolt; (4) aft upper attaching points; (5) diagonal assembly; (6) aft diagonal; (7) and (8) attaching bolts; (9) pads; (10) and (11) forward attaching bolts; (12) pads; (13) fore diagonal attaching point; (14) bay assembly; (15) yoke attaching bolt; (16) and (17) diagonals; (18) diagonal attaching point; (19) lower truss bolt; (20) truss.

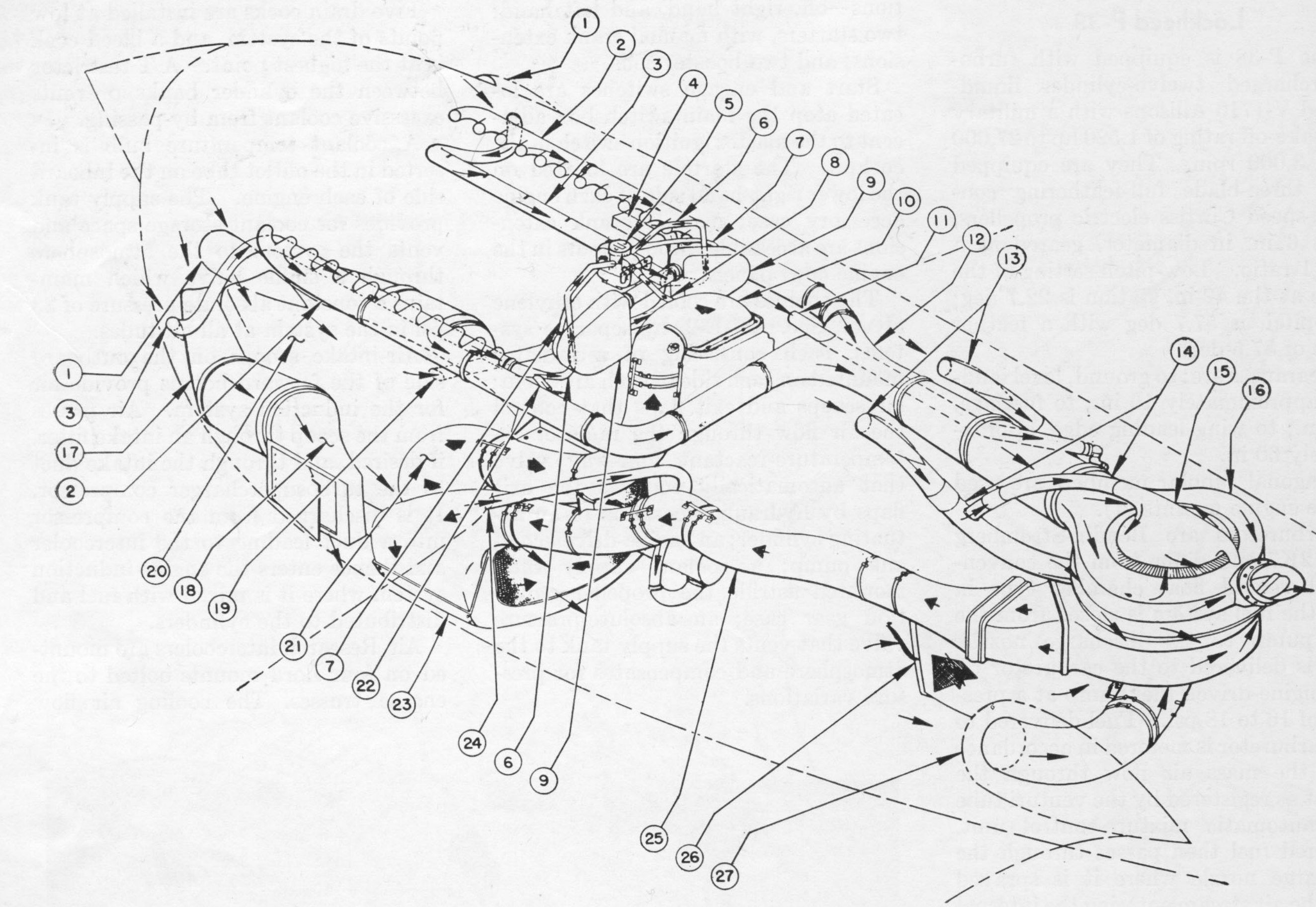
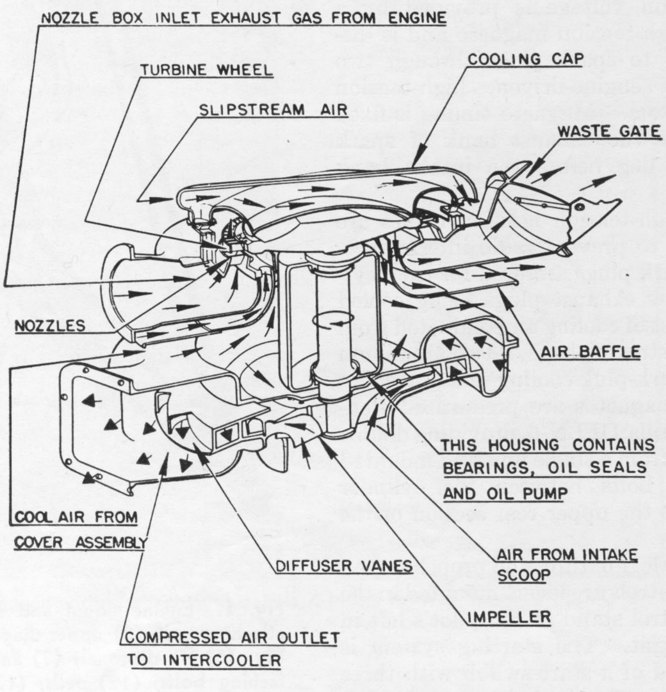


Fig. 2. Phantom view giving supercharger installation; (1) scoop–exhaust manifold and shroud; (2) exhaust manifold; (3) spark-plug blast tube; (4) electrical relay box; (5) magneto; (6) magneto blast tube; (7) air pressure to distributor housing; (8) air pressure to magneto unit; (9) distributor housing; (10) carburetor intake duct; (11) intensifier tube–cabin and armament heat; (12) exhaust Y tail pipe; (13) cover assembly–supercharger baffles; (14) blast-tube supercharger main bearing and cooling baffles; (15) cooling cap supercharger; (16) B-33 supercharger (for detail of supercharger, see 3*b*); (17) intake scoop–oil-cooler regulator; (18) exit duct–oil-cooler regulator; (19) duct to electrical oil-cooler relay; (20) intake scoop–intercooler; (21) exit duct–intercooler; (22) blast tube to tachometer generator; (23) intercooler unit; (24) generator blast tube; (25) intake duct–intercooler; (26) air filter, (27) supercharger air-intake scoop.



CUTAWAY SHOWING OPERATION OF SUPERCHARGER

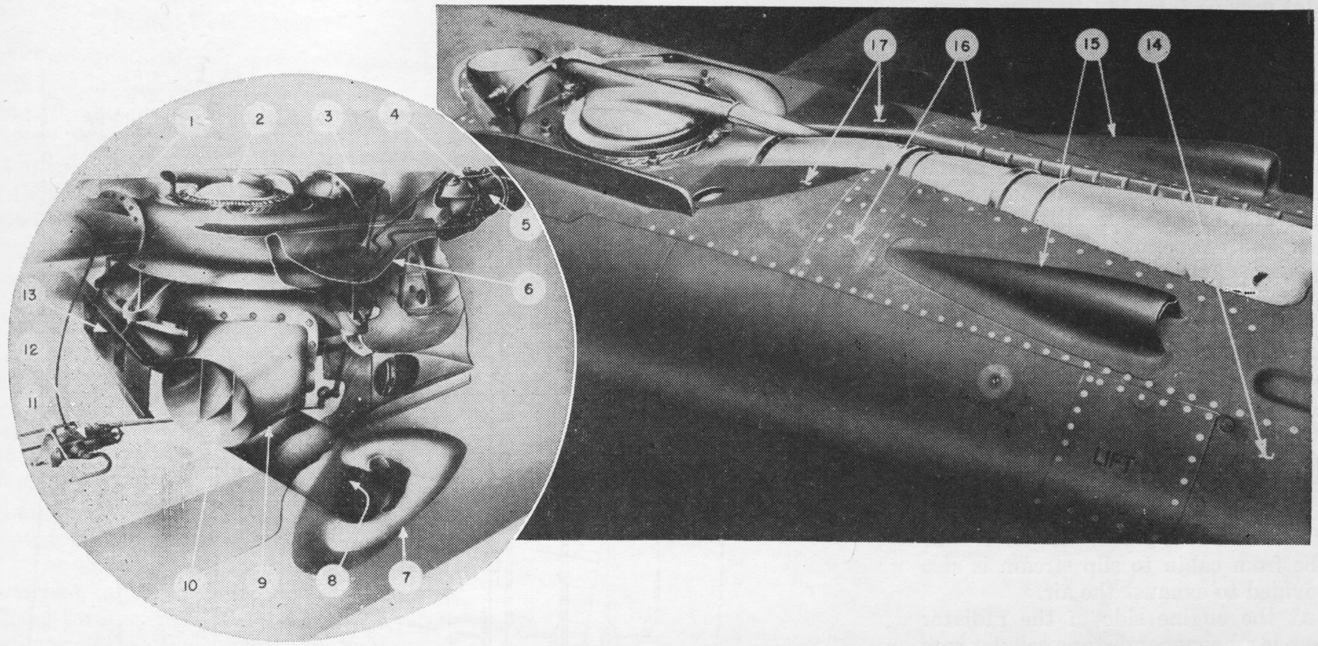


Fig. 3. Supercharger installation: (1) armor plate; (2) supercharger; (3) waste gate; (4) oil-tank vent line; (5) oil tank; (6) stainless-steel structure; (7) supercharger air-intake scoop; (8) air intake; (9) duct; (10) air outlet to intercooler; (11) to engine oil system; (12) supercharger regulator; (13) center section rear shear beam; (14) panel assembly; (15) and (16) cover assemblies; (17) inboard deck assembly.

through the intercooler radiator may be manually controlled by an electric motor-operated shutter.

The superchargers (2, 3) are General Electric exhaust-driven turbo-type mounted as previously mentioned immediately behind the rear shear beam of the wing in the forward booms.

De Havilland Mosquito

The Mosquito is powered by two Packard Rolls-Royce Merlin 31, 33 or 225 engines. They are mounted on four feet cast integral with the crankcase. To support the engines in the plane, a tubular steel frame is provided. This consists of two units, one left and the other right, which are attached to brackets bolted to the face of the front spar. Ribs 3 and 4, immediately to the rear of these brackets, give them the necessary torsional rigidity.

The interesting feature of this structure is the combination of engine mounting frames with fixed landing gear tubular members. This makes an inverted bridge truss that not only supports the engine but strengthens the landing gear. The construction transmits the engine inertia loads directly to the landing gear instead of through the wing structure when landing.

To take engine torque and provide lateral stability for the engine, transverse and diagonal bracing is incorporated in each mount. The construction of the spar attachment brackets for the landing gear and engine is of unusual interest. Ordinarily it is a quite difficult problem to make the transition from metal to wood, but the problem is handled in a very direct and simple manner in this case. Even the flapjack and center hinge support are tied into this structure to get maximum bracing.

Sixteen gallons of water and ethylene glycol mixture are used in each engine, with provision for an expansion header tank just ahead of the cylinders (1). Filler opening for the cooling system is in the header tank. A thermometer is provided to indicate engine temperature on the instrument panel.

Thermostats and removable radiator air-duct flaps control engine temperature. The flaps are controlled by the pilot.

The automatic thermostatic valves are designed so that only jacket coolant is circulated up to 185°F. This provides a quick warm-up. Above 221°F all coolant circulates through the radiators.

Each engine has its own cooling system for both coolant and lubricating oil (2). The connections are short and direct from engine to radiator core.

The radiator is located on the front spar between the fuselage and engine nacelle. The air duct forms the leading edge at this point. The radiator unit cover forms the top of the wing; the same is true of the bottom.

Radiator cores are mounted in an aluminum frame structure bolted to the front of the main wing spar. The lower connections are tubular in form, provided with a screw adjustment for length.

The top is attached to the wing spar by the five channel-shaped ribs which go over the top of the radiator cores. These ribs have lightening holes through which the service pipes are threaded. Diagonal tubular braces at the center steady the whole installation laterally. They also take reactions from the electropneumatic ram which operates the cooling flaps in the air-outlet stream.

Air enters the radiator duct through

a slot in wing L.E., but the flow is controlled by the position of the outlet flap below and behind the radiator cores. A back plate streamlines the air beneath the front spar when the flap is open. Flaps for each engine are separately controlled by switches at the pilot's hand. The electropneumatic rams are designed to close the flaps when the temperature is below 230°F and open them when it reaches 239°F, maximum.

The radiator core is divided into three sections. A small section with a special outlet passage is located next to the fuselage. There is a hand-operated flap in this passage controlled by the pilot. When the flap is closed, all air passing through this section of the radiator goes into the cabin through an inlet tube inside the fuselage. An air tube from cabin to slip stream is also provided to exhaust the air.

At the engine side of the radiator there is a honeycomb-type cellular core to cool oil in the same air stream but entirely separate from the engine-cooling section. The engine-cooling radiator core is of the fin and flat tube type.

All oil and liquid couplings are made with the Alvimo design. The thermostatic relief valve mounted on the header tank controls pressure in the cooling system and suppresses boiling. It also admits air to the header when temperature falls, thus relieving the system of subatmosphere internal pressures. A relief valve opens up at 2-atm pressure. The vent tube discharges just aft of the exhaust stacks.

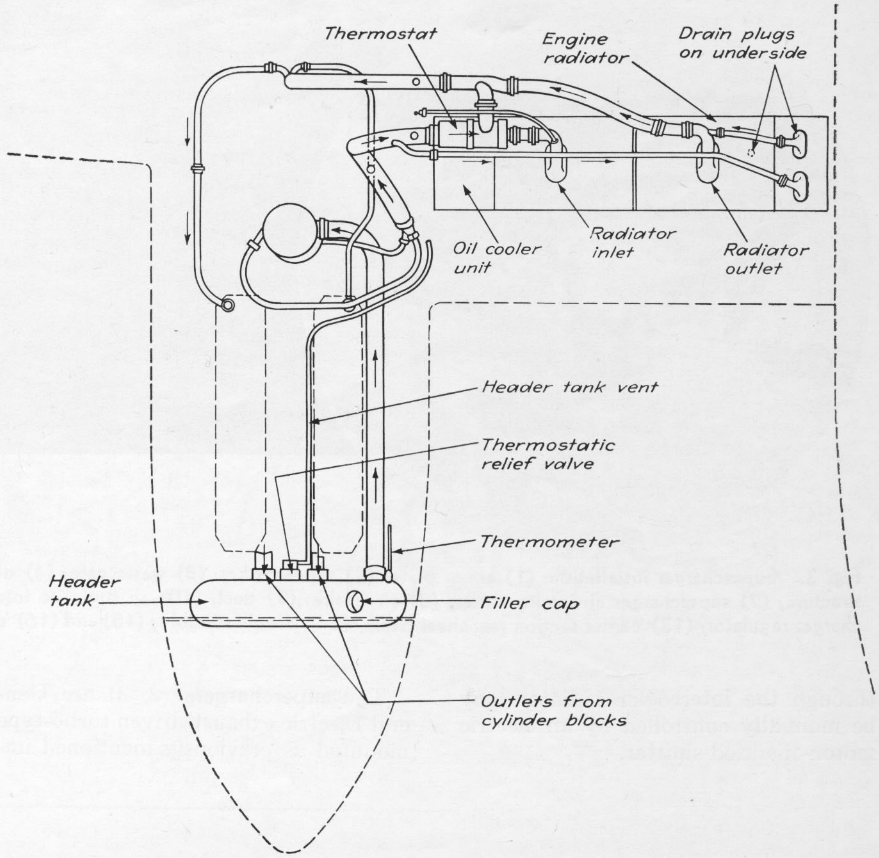


Fig. 1. Right-hand engine cooling system with the radiator between the nacelle and the fuselage. The left-hand installation is similar.

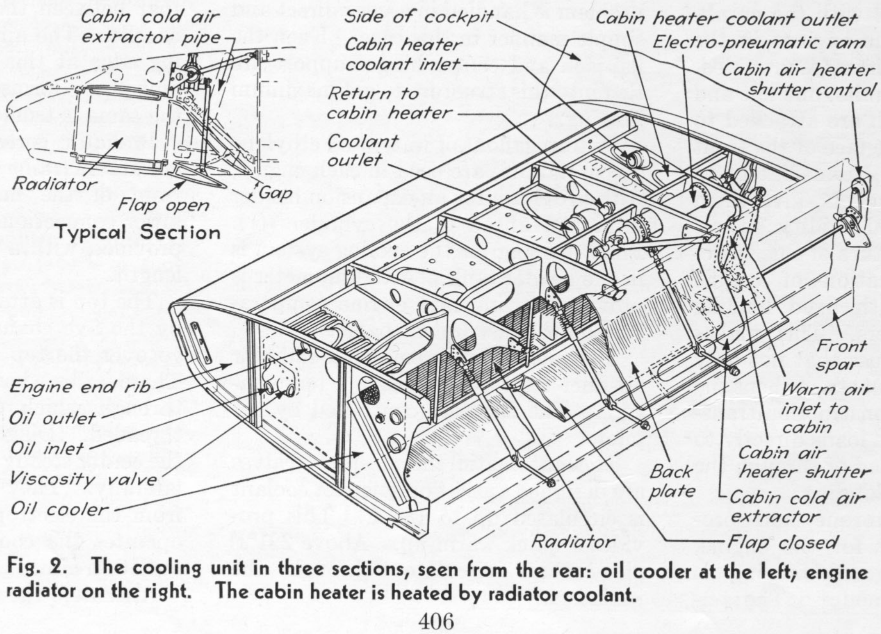


Fig. 2. The cooling unit in three sections, seen from the rear: oil cooler at the left; engine radiator on the right. The cabin heater is heated by radiator coolant.

Bristol Beaufighter

Two Bristol Hercules engines are installed in the nacelles near the outboard ends of the Beaufighter's center plane. The nose of each cowling is formed by an exhaust collector ring, while the air flow is controlled by flaps at the trailing edge.

Fuel is carried in four main tanks: two in the center wing (one on each side), and one in each outer wing. The fuel is fed to the carburetor by engine-driven pumps.

An oil tank is fitted for each engine on top of the wing at each nacelle, and separate oil coolers are mounted in the outer wings. To assure an adequate amount of oil when starting, a high initial oil-pressure device is incorporated in each engine.

The engines are fitted with electric starters, and for maintenance work, hand-turning gear is provided. Constant-speed feathering hydromatic propellers are fitted.

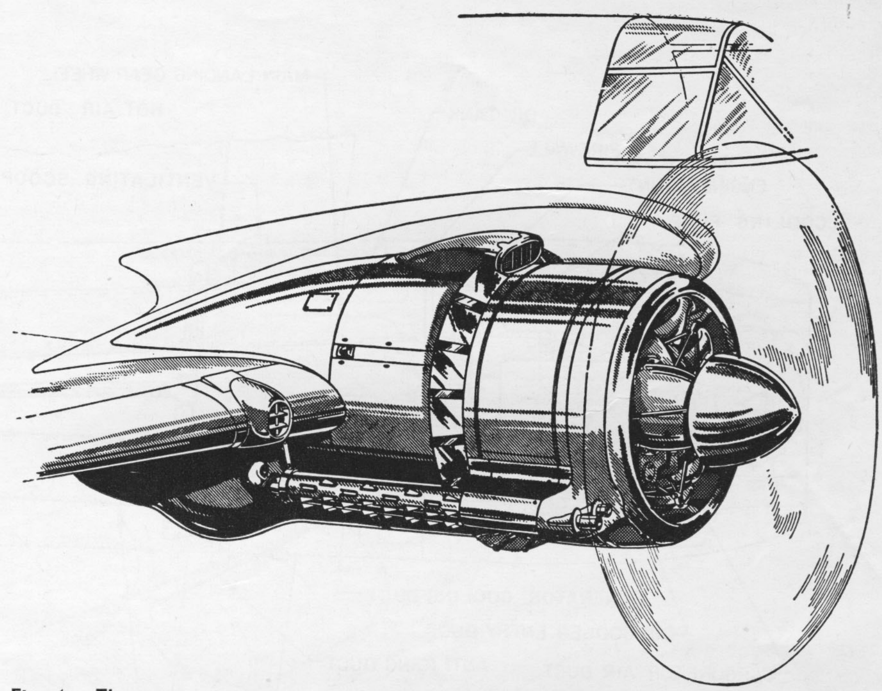


Fig. 1. The power unit is equipped with Bristol Hercules 1,650-hp sleeve-valve engines mounting full feathering propellers. The engine units are easily detachable and are interchangeable. Low drag cowling has flaps at the rear to control the engine temperature. An air scoop for the oil cooler is above the engine at the rear.

Each power-plant mounting is of welded steel tubing attached to the main structure, near the outboard ends of the center wing, at five points: three on the front spar and two on the nacelle structure. The tubes at the rear attachment joints are split, wrapped around, welded to a steel bushing, and a steel gusset plate is welded over the joint. The engine ring is bolted to four points on the engine mounting, joints being formed by a steel barrel to which the tubes are secured by welding, and steel gussets.

The engine ring is a steel tube of square section with welded-steel side plates and bushings for the ring attachment, and for the seven engine attachment points.

Two magnetos on each engine are controlled by separate switches combined in one unit below the instrument-flying panel in the cockpit. Switch knobs are prevented from being moved to the ON position by an extension bar on the switch for the landing gear and tail-wheel electrical position indicators (mounted alongside on the left side) when that switch is off.

A booster magneto on a bracket forward of the fire wall supplies starting current to the main magnetos. In the high-tension cables connecting the booster to the main magnetos are spark gaps which relieve the booster windings when the engines are running normally. A tumbler switch, mounted in each engine nacelle above the landing gear pivot and accessible only when the landing gear is down, controls the starting magneto. The hand-turning gear also is connected by a chain drive to the starting magneto.

Two temperature gauges are mounted on the instrument panel alongside the magneto switches and show the temperature of the No. 8 cylinders.

The Bristol Hercules engine is a fourteen-cylinder double-row sleeve-valve type with a total capacity of 2,360 cu in. (38.7 liters). The bore is 5¾ in. and the stroke 6½ in. The production series of the Hercules fitted in the plane develops more than 1,650 bhp and is fitted with a two-speed supercharger. Provision is made for constant-speed multiblade propellers for the hydromatic or electrically controlled type.

The engine is mounted as a complete self-contained, cowled and cooled installation power unit, with flame-damped exhaust system. The engine mounting is designed for quick four-point connection to the air frame (1).

Convair Liner

Two Pratt & Whitney R-2800 engines power the Convair Liner with Hamilton standard, three-blade, automatic full-feathering and reversible propellers, 13 ft 1 in. in diameter, or Curtiss electric props of the same specifications.

With water injection, these engines develop 2,400 hp each; without water, 2,100 hp each.

The engine nacelles (1) are divided into three compartments, separated by stainless-steel walls. Zone 1 contains the engine; zone 2 is the accessory section; and zone 3 is the wheel well.

An "orange-peel" cowling (3) which surrounds the engine is made in four sections, each hinged at the fire wall. The cowling can be unlatched and opened in a few seconds, exposing the entire engine for easy maintenance.

Carburetor air is ducted through the top cowl panel. Entrance to the carburetor-air duct is on the inside of the

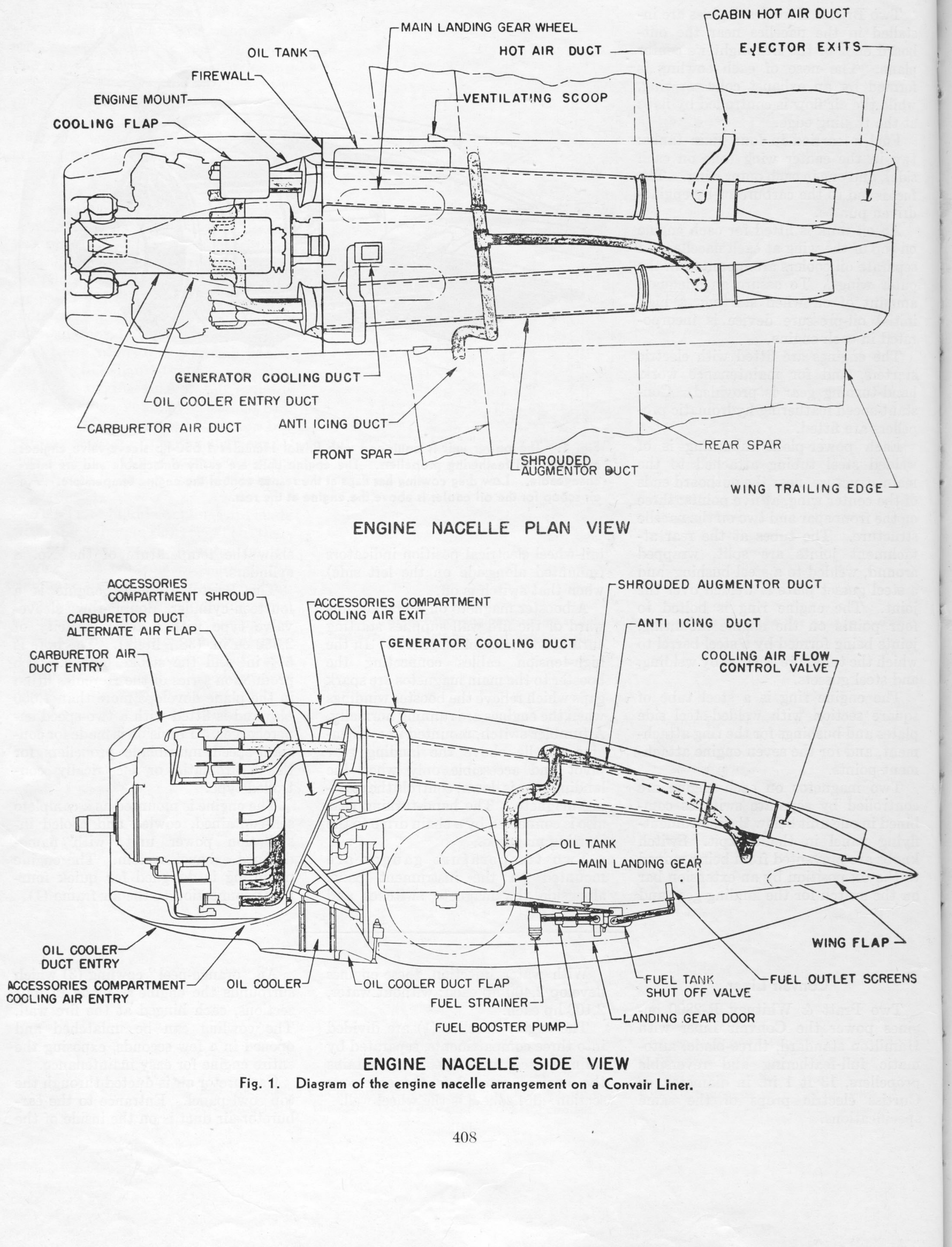


Fig. 1. Diagram of the engine nacelle arrangement on a Convair Liner.

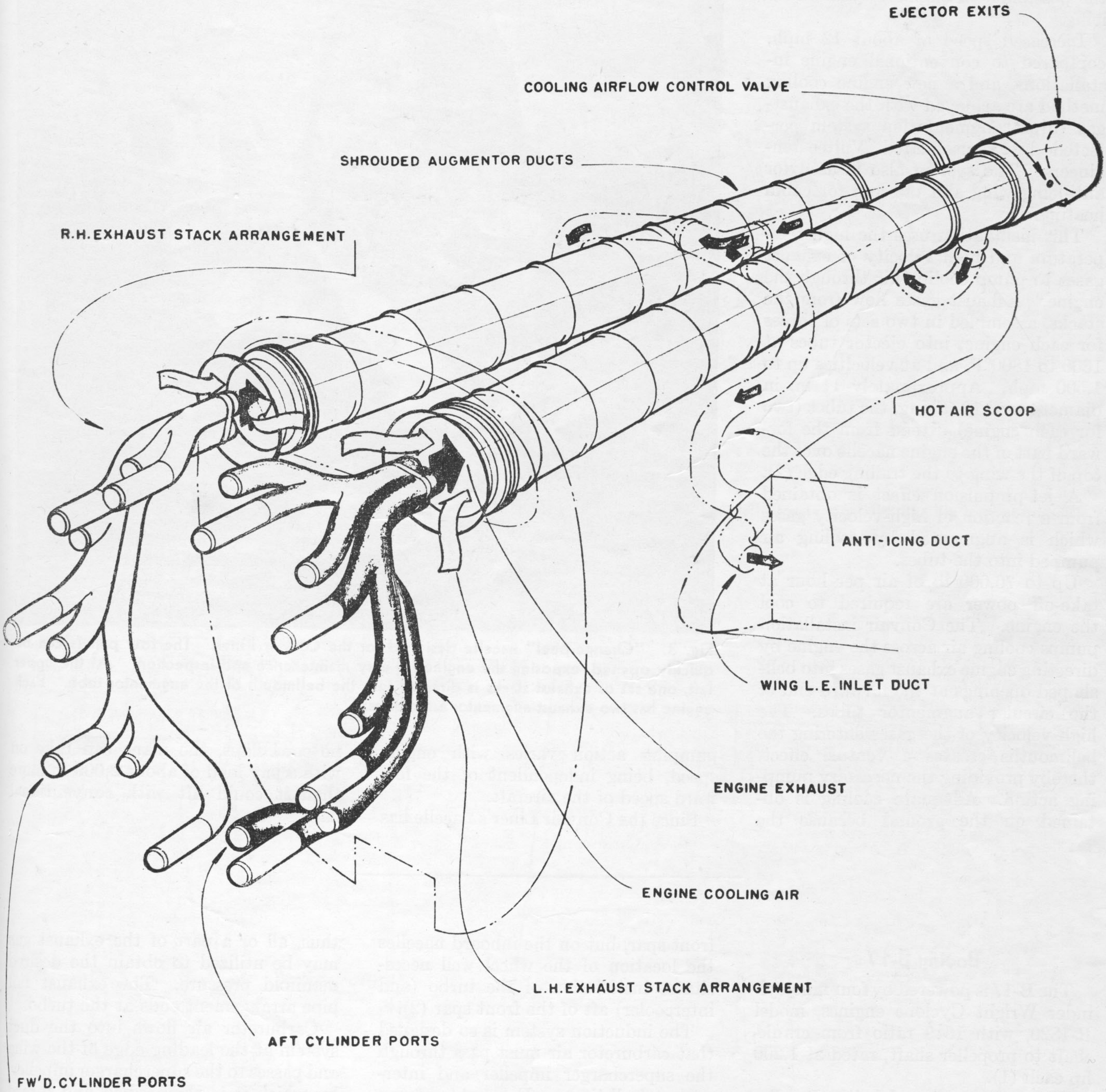


Fig. 2. The exhaust-system ejector tubes of the Convair Liner.

cowl, just forward of the engine. It is designed to permit moisture droplets to pass by the opening. This feature provides the carburetor with air that is practically moisture-free and reduces the possibility of engine blower throat icing.

Increased speed of about 12 mph, compared to conventional engine installations, and a new engine cooling method are achieved with the exhaust-gas thrust augmentation system perfected by Consolidated Vultee engineers. The system also is used for anti-icing wing and tail and for cabin heating.

This installation uses the high temperature and high velocity of exhaust gases to pump cooling air through the engine. Exhaust gases flow from the stacks, assembled in two sets of threes for each engine, into ejector tubes at 1600 to 1800°F, and at velocities up to 1,500 mph. Approximately 11 in. in diameter and 12 ft long, the tubes (two for each engine) extend from the forward part of the engine nacelle over the top of the wing to the trailing edge (2).

A jet-propulsion effect is obtained from a reaction of high-velocity gases which is augmented by cooling air pumped into the tubes.

Up to 70,000 lb of air per hour at take-off power are required to cool the engine. The Convair installation pumps cooling air across the engine by directing engine exhaust gases into bell-shaped openings at the forward end of the circular augmentor tubes. The high velocity of the gases entering the bellmouths creates a venturi effect, thereby providing the necessary pumping action. Adequate cooling is obtained on the ground because the pumping action varies with engine speed, being independent of the forward speed of the aircraft.

Since the Convair Liner's nacelle has no cowl flaps, the plane can take off with a pay load of about 2,000 lb more than it could lift with conventional flaps.

Fig. 3. "Orange-peel" nacelle designed for the Convair Liner. The four panels can be quickly opened, exposing the engine for easy maintenance and inspection. At the upper left, one set of exhaust stacks is directed into the bellmouth of the augmentor tube. Each engine has two exhaust-augmentor assemblies.

Boeing B-17

The B-17 is powered by four nine-cylinder Wright Cyclone engines, model R-1820, with 16:9 ratio from crankshaft to propeller shaft, rated at 1,200 hp each (1).

They are equipped with Bendix-Stromberg PD-12H2 injection carburetors and General Electric B-22 turbosuperchargers.

The supercharger (3) is installed in the engine exhaust system at the bottom of the nacelle. On the outboard nacelles the location is forward of the front spar, but on the inboard nacelles the location of the wheel well necessitates installation of the turbo (and intercooler) aft of the front spar (2).

The induction system is so designed that carburetor air must pass through the supercharger impeller and intercooler at all times. Exhaust-gas pressure drives the impeller by flowing through a nozzle box where the gas is directed against a turbine wheel mounted on the lower end of the impeller shaft. Flow of the exhaust gas through the turbine wheel is controlled by the waste gate in the nozzle box; thus, all or a part of the exhaust gas may be utilized to obtain the desired manifold pressure. The exhaust tail pipe arrangement ends at the turbo.

Carburetor air flows into the duct system at the leading edge of the wing and passes to the supercharger impeller, by which it is compressed and forced through the intercooler into the carburetor. A relief valve is provided in the supercharger intake duct to permit the entrance of air to the supercharger if the flow through the inlet is accidently restricted.

The inboard intercooler is located

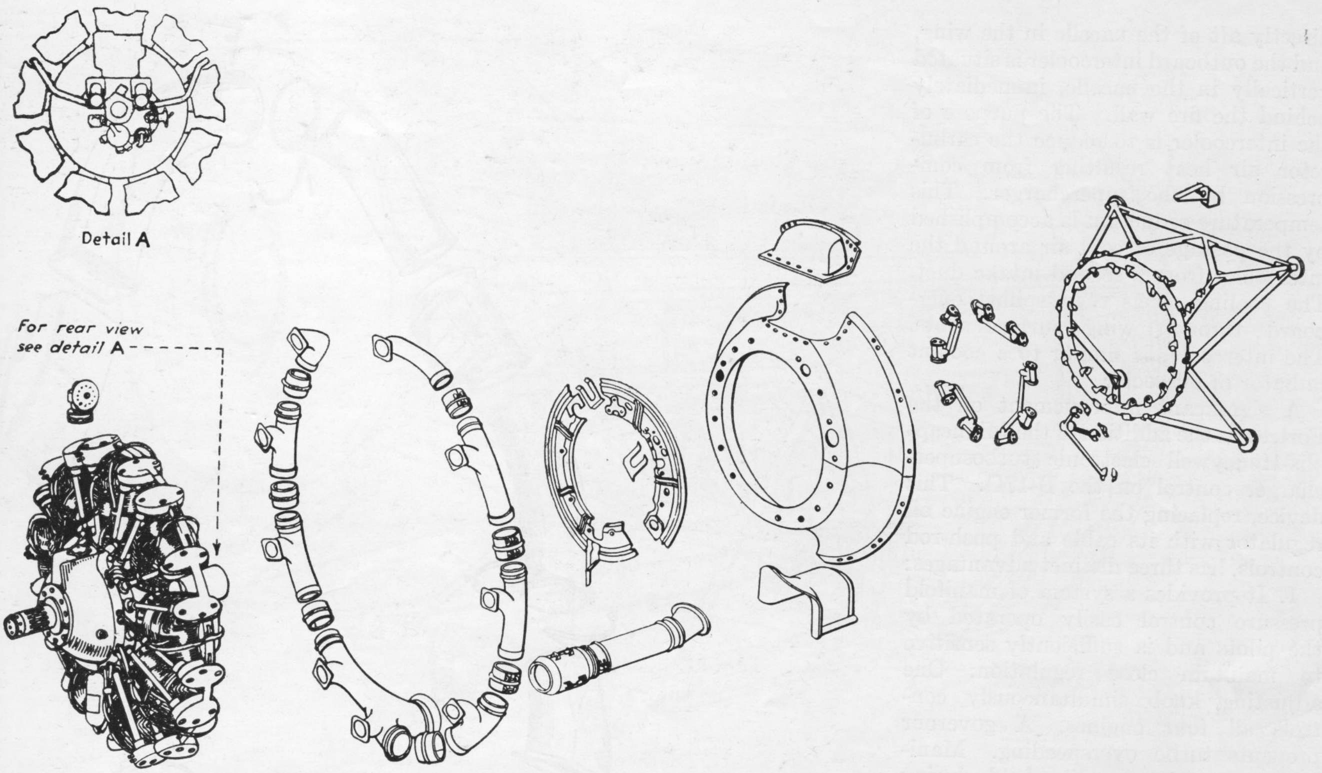


Fig. 1. Details of the engine installation include exhaust collector-ring assembly, cabin heat tail-pipe section with flexible joint at the left end, and dynamic suspensions (left of the engine mount).

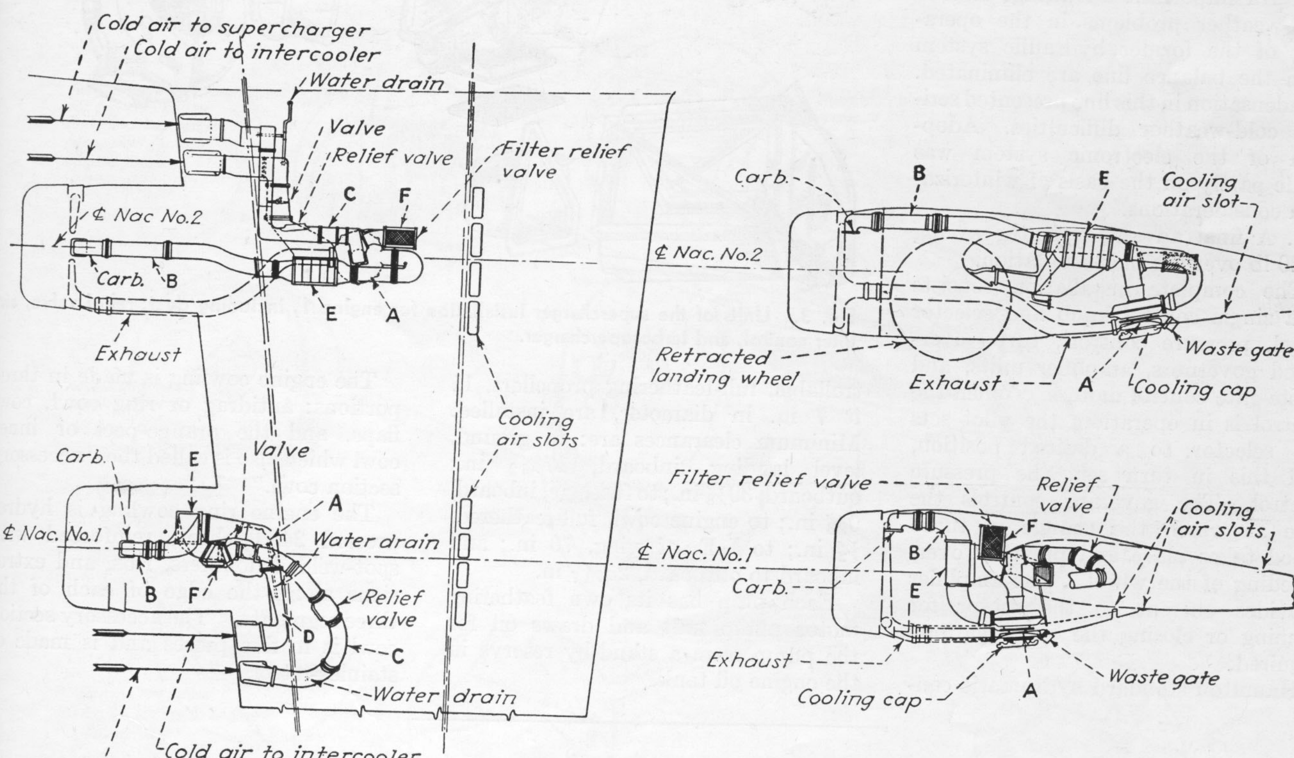


Fig. 2. Diagrammatic representation of the supercharger installation. Left, plan view of the left-hand wing and nacelles (right-hand, similar); upper right, left-hand view of No. 2 nacelle; lower right, left-hand view of No. 1 nacelle: (*A*) supercharger; (*B*) pressure duct; (*C*) air duct; (*D*) intercooler duct; (*E*) intercooler; (*F*) air filter frame.

directly aft of the nacelle in the wing, and the outboard intercooler is situated vertically in the nacelle, immediately behind the fire wall. The purpose of the intercooler is to reduce the carburetor air heat resulting from compression by the supercharger. This temperature reduction is accomplished by the passage of cold air around the intercooler from a second intake duct. The cooling air is then spilled overboard through wing surface slots. The intercooler is similar to a coolant radiator or oil cooler.

A significant improvement on the Fortress is the addition of the Minneapolis-Honeywell electronic turbosupercharger control on the B-17G. This device, replacing the former engine oil regulator with its cable and push-rod controls, has three distinct advantages:

1. It provides a system of manifold pressure control easily operated by the pilots and is sufficiently sensitive to maintain close regulation. One adjusting knob simultaneously controls all four engines. A governor prevents turbo overspeeding. Manifold pressure is readily held during take-off, climb, cruise, or glide.

2. An important advantage is that cold-weather problems in the operation of the former hydraulic system with the balance line are eliminated. Condensation in this line presented serious cold-weather difficulties. Adoption of the electronic system was made partly on the basis of winterization considerations.

3. A final advantage is the saving of 30 lb over the old installation.

The complete installation consists of a single control knob and selector panel, pressure controls, turbo overspeed governors, amplifier units, and waste-gate control motors. When the control is in operation, the pilot sets the selector to a desired position, and this in turn sets the pressure control. The governor controls the rate at which the change in turbo speed takes place and prevents overspeeding of the wheel. The amplifier provides current to the motor for opening or closing the waste gate as required.

Hamilton standard hydromatic controllable, full-feathering propellers, 11 ft 7 in. in diameter, are installed. Minimum clearances are: to ground, level landing, inboard, $17\frac{9}{32}$ in.; outboard, $30\frac{1}{8}$ in.; to fuselage, inboard, $9\frac{3}{8}$ in.; to engine cowl, full-feathered, $\frac{1}{2}$ in.; to L.E. of wing, 70 in.; and inboard to outboard, $25\frac{7}{17}$ in.

Each prop has its own feathering motor pump unit and draws oil for the pump from a stand-by reserve in the engine oil tank.

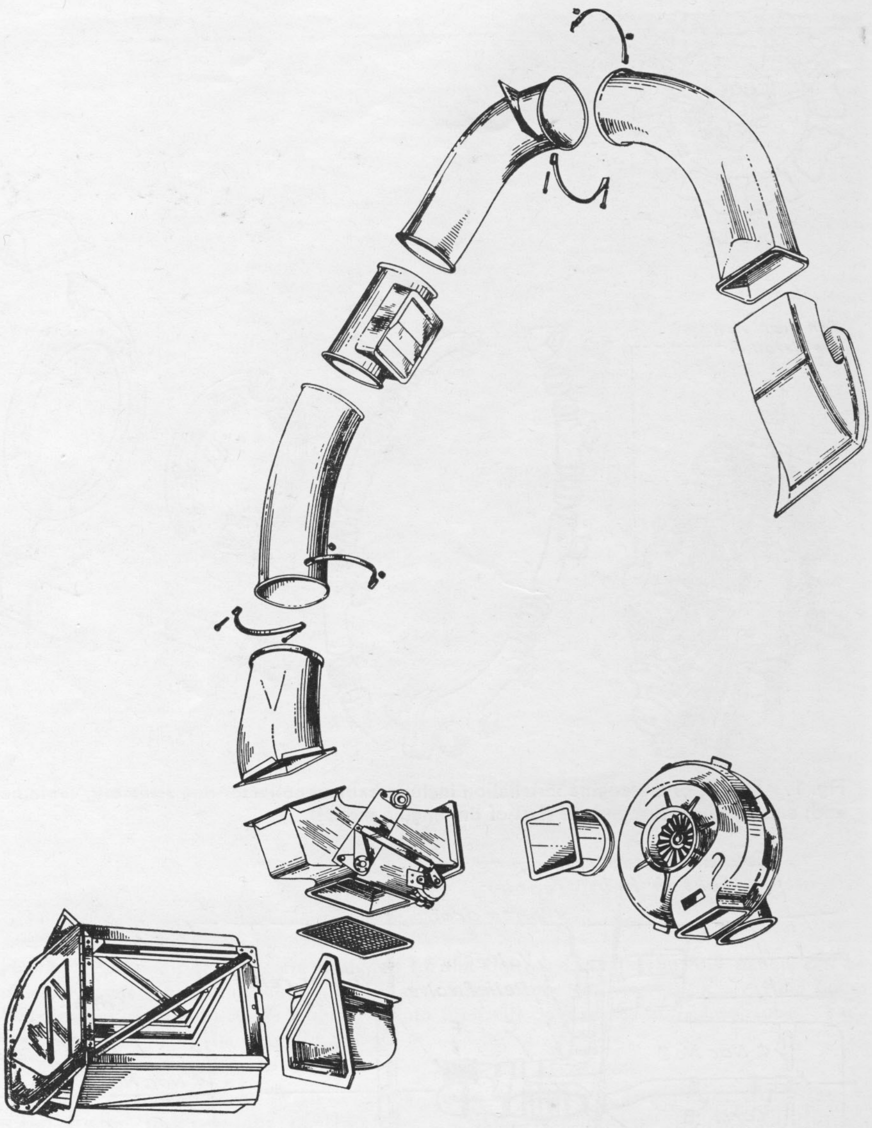


Fig. 3. Units of the supercharger installation for engine 1, including duct, relief valve, air filter control, and turbosupercharger.

The engine cowling is made in three portions: antidrag or ring cowl, cowl flaps, and the orange-peel or inner cowl which also is called the "accessory section cowl."

The engine ring cowling is hydropressed 24ST sheet, reinforced with spot-welded doublers, ribs, and extrusions along the edge of each of the three segments. The accessory section cowl is in five pieces and is made of stainless steel.

Canadair North Star

The North Star airplane is powered by four liquid-cooled Rolls-Royce T.M.L. Merlin 620 engines. All power plants are interchangeable between all four positions. The design provides for quick changing of power plants and accessibility to various parts for maintenance. Provision is made for slinging the engine from the engine rocker covers without removing the major

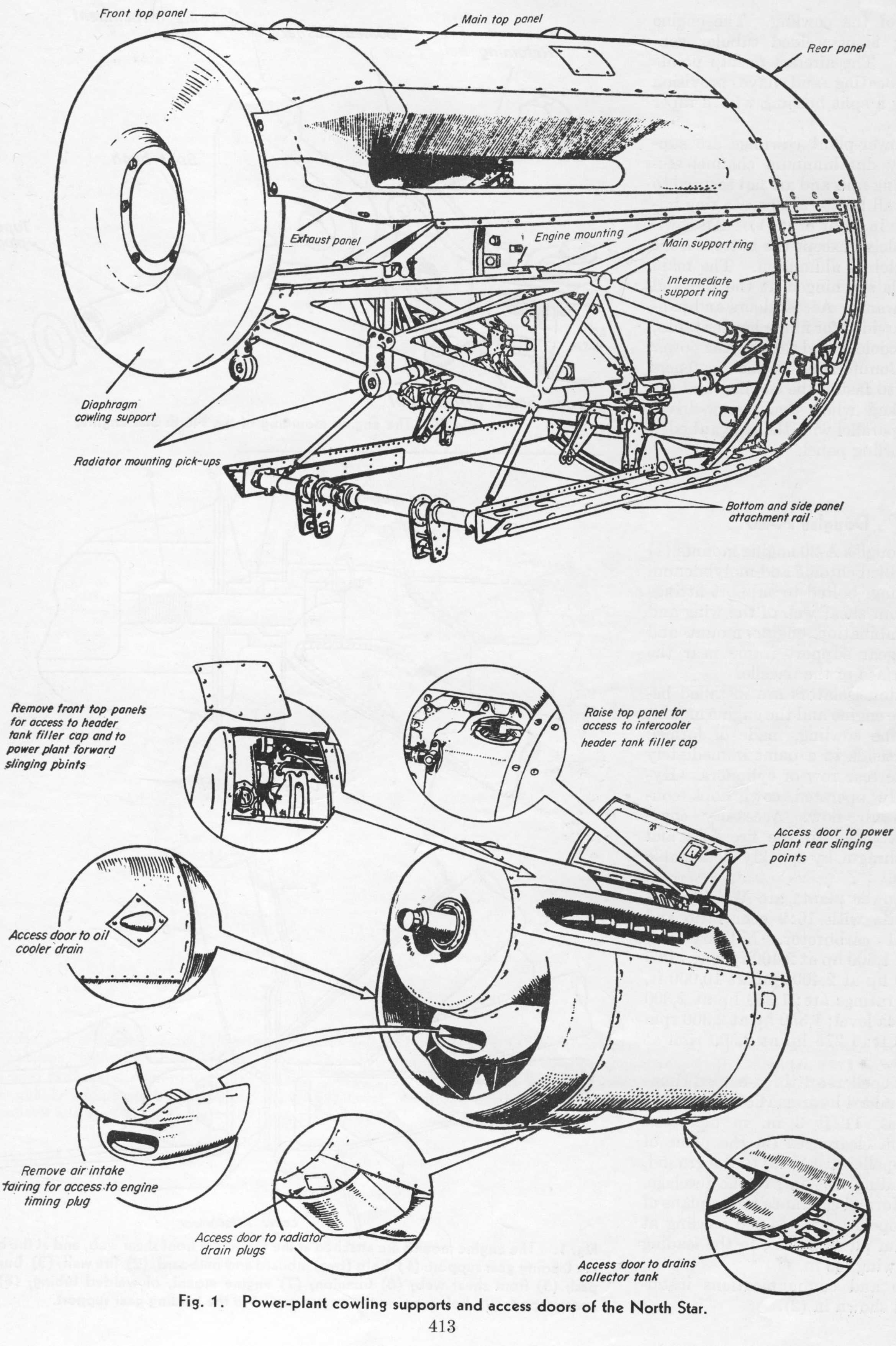


Fig. 1. Power-plant cowling supports and access doors of the North Star.

portions of the cowling. The engine mounting is of welded tubular construction. The aircraft pickup points are self-locating and have provision for fitting a split bushing with a taper bolt (2).

The power-plant cowlings are supported by duraluminum channel section cowling rails and are not secured to the fire wall but to a separate ring immediately in front of it (1). All cowlings are alclad except the bottom front scoop which is aluminum. The main top panels are hinged at the top and open outward. Access doors and panels are provided for filling header tanks, draining coolers, and slinging the power plant. Countersunk Dzus fasteners are used to fasten the cowling and are fully locked when their screw-driver slots are parallel with the relevant edge of the cowling panel.

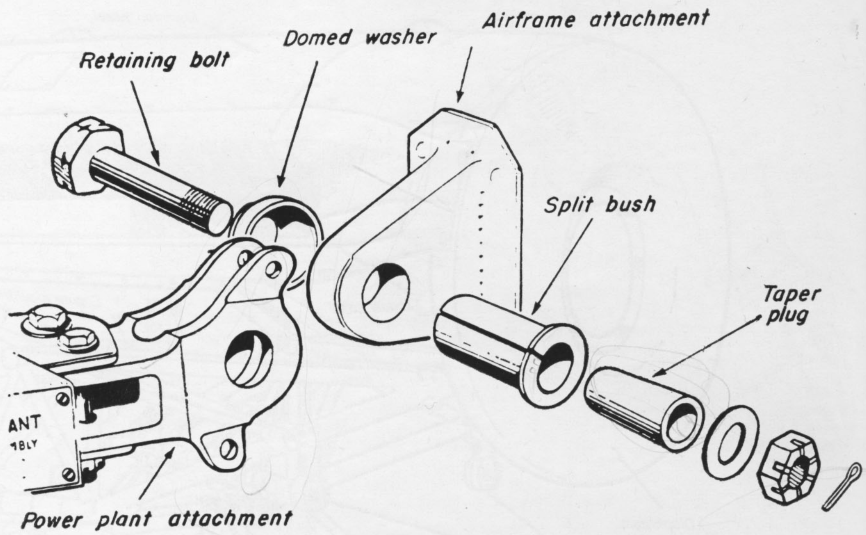


Fig. 2. The engine mounting of the North Star engine.

Douglas A-20

The Douglas A-20 engine mounts (1) are of welded chrome and molybdenum steel tubing, bolted to support fittings at the front shear web of the wing and to a combination engine mount and landing gear support frame near the lower surface of the nacelle.

Vibration isolators are installed between the engine and the engine mount. The engine cowling, made of formed sheet, extends to a point immediately aft of the rear row of cylinders. Hydraulically operated cowl flaps control the air flow. Accessory cowling is attached to the fire wall and the diaphragm by quickly detachable fasteners.

The power plants are Wright GR-2600 units with 16:9 gear ratio and PD-12K1 carburetor. Military ratings are: 1,600 hp at 2,400 rpm at 1,000 ft; 1,400 hp at 2,400 rpm at 10,000 ft. Normal ratings are: 1,350 hp at 2,300 rpm at sea level; 1,350 hp at 2,300 rpm at 5,000 ft; 1,275 hp at 2,300 rpm at 11,500 ft.

The propellers are three-bladed Hamilton standard hydromatic full-feathering types, 11 ft 3 in. in diameter. Minimum clearances (in the plane of each propeller disk) are: to the ground, level landing, 9½ in.; to the fuselage, 9 in. Normal clearance to the plane of each propeller disk: to the cowling at maximum pitch, ½ in.; to the leading edge of wing, 33 in.

Radio and communications installation is shown in (2).

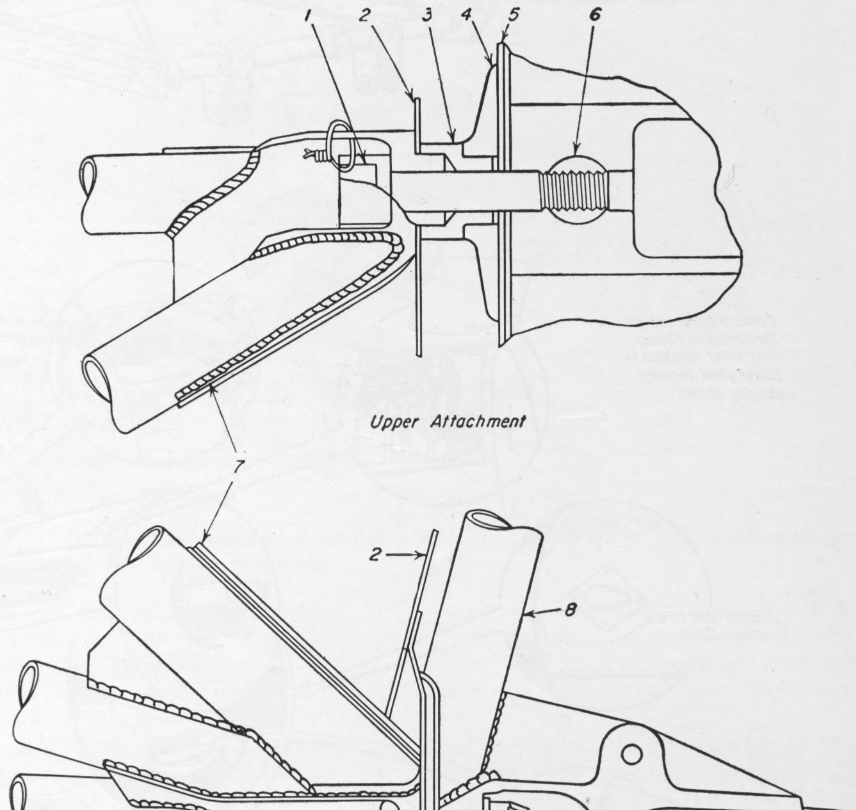


Fig. 1. The engine mounts are attached at the top to the front shear web, and at the bottom of the landing gear support: (1) bolts (two) inboard and outboard; (2) fire wall; (3) bushing; (4) pad; (5) front shear web; (6) trunnion; (7) engine mount, of welded tubing; (8) landing gear support; (9) bolt securing the engine mount to the landing gear support.

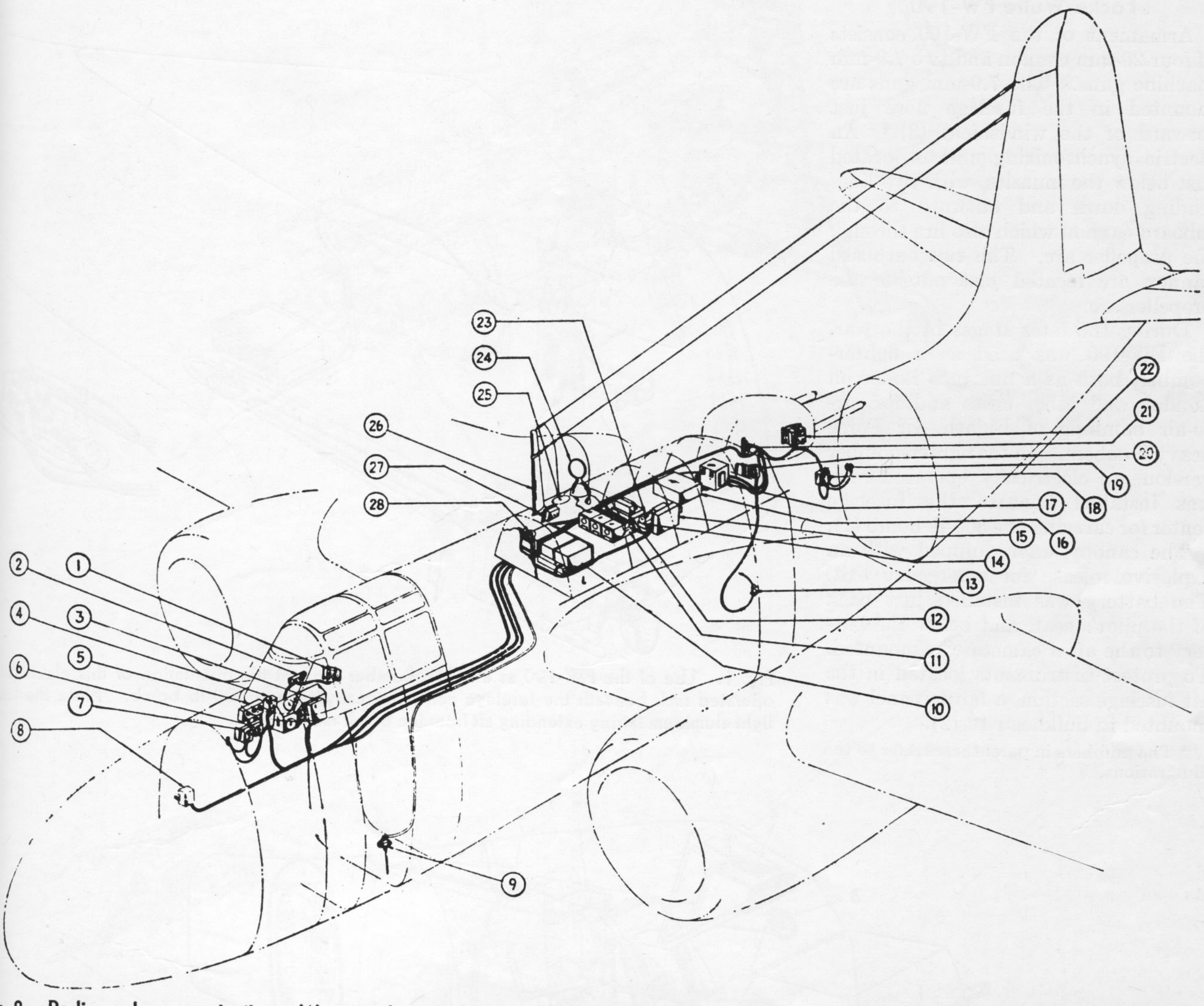


Fig. 2. Radio and communications: (1) azimuth control unit; (2) switch box; (3) radio compass control; (4) transmitter control box; (5) receiver control box; (6) switch box; (7) jack box; (8) radio interphone filter; (9) antenna connection; (10) transmitter; (11) receiver; (12) modulator unit; (13) turret swivel joint; (14) amplifier; (15) main radio junction box; (16) radio compass receiver; (17) identification radio; (18) lower gunner interphone box; (20) jack box; (21) turret interphone terminal strip; (22) control box; (23) dynamotor; (24) loop; (25) antenna insulator and lead-in; (26) mast; (27) antenna relay; (28) switch box.

Chapter IX. MISCELLANEOUS DESIGN DETAILS

PART 1. SINGLE-ENGINE AIRCRAFT

Focke-Wulfe FW-190

Armament of the FW-190 consists of four 20-mm cannon and two 7.9-mm machine guns. The 7.9-mm guns are mounted in the fuselage nose just forward of the windshield (3).* An electric synchronizing unit is located just below the muzzles, with two lines leading down and outward to the inboard cannon which also fire through the propeller arc. The two outboard cannon are located just outside the propeller arc.

During the later stages of the war, the FW-190 was used as a fighter-bomber, both as a nuisance raider on London and other cities and for air-to-air bombing of Eighth Air Force heavy bombers. In the fighter-bomber version, an electrically operated rack was installed beneath the fuselage center for carrying one 500-lb bomb (1).

The canopy was equipped with an explosive release for emergency exit. The battery was installed just back of the pilot's seat, and below the battery to the aft a camera was mounted. To protect instruments located in the aft fuselage section, a fabric panel was mounted in bulkhead 12 (2).

* The numbers in parentheses refer to the illustrations.

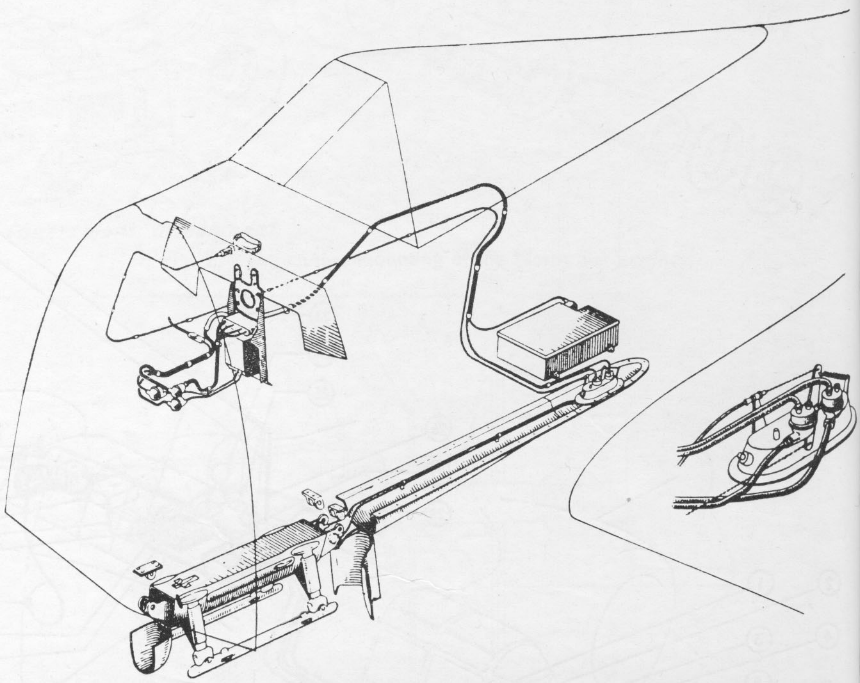


Fig. 1. Use of the FW-190 as a fighter-bomber brought the installation of this electrically operated rack beneath the fuselage center for carrying one 500-lb bomb. Note the long light aluminum fairing extending aft from the bomb rack itself.

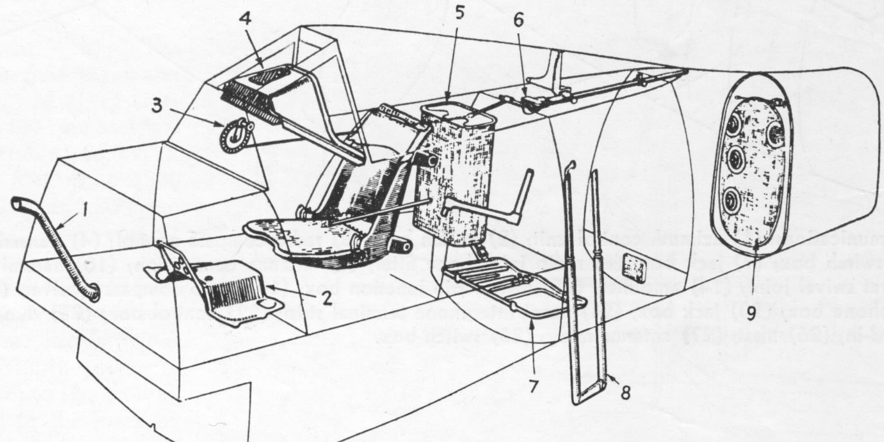


Fig. 2. Accessories in the FW-190 fuselage section: (1) hot-air supply to cockpit; (2) cover over fuel pumps and electric junction boxes; (3) handle moving canopy; (4) armor-and bulletproof glass; (5) battery; (6) explosive canopy release; (7) camera mount; (8) step which telescopes up into the fuselage; (9) fabric panel in bulkhead 12 to protect instruments located in the aft fuselage section.

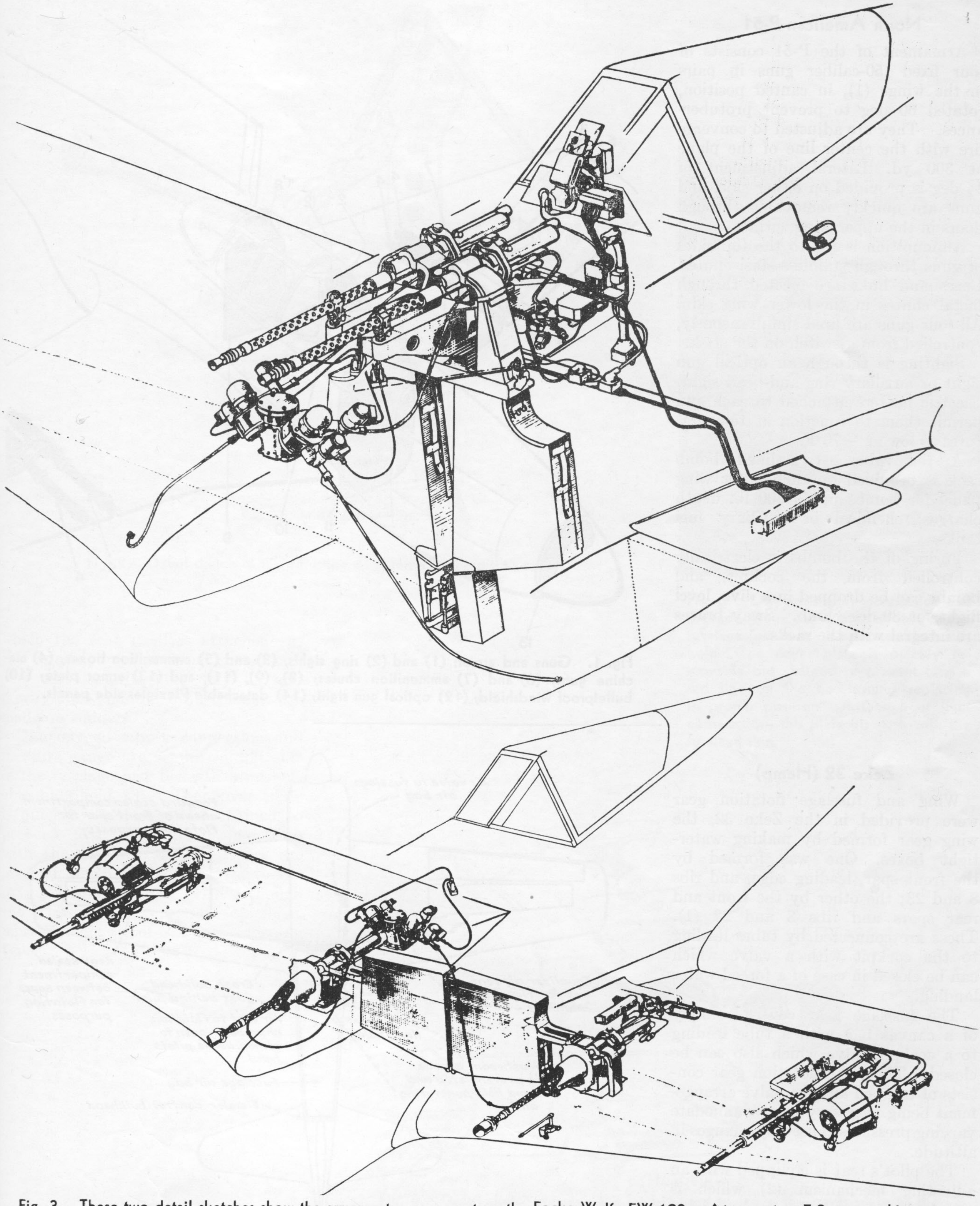


Fig. 3. These two detail sketches show the armament arrangement on the Focke-Wulfe FW-190. At *a* are two 7.9-mm machine guns with electric synchronizing unit just below the muzzles; two lines leading down go to inboard 20-mm cannon, which also fire through the propeller arc. Two-outboard 20-mm cannon (also shown in *b*) are located just outside the propeller arc.

North American P-51

Armament of the P-51 consists of four fixed .50-caliber guns in pairs in the wings (1), in canted position, rotated 60 deg to prevent protuberances. They are adjusted to converge fire with the center line of the plane at 300 yd. Lateral adjustment of ½ deg is provided on either side, and guns are quickly removable through doors in the upper wing surface.

Ammunition is fed to the top sides of guns through stainless-steel chutes. Cases and links are ejected through metal chutes in the lower wing skin. All four guns are fired simultaneously, controlled from a switch on the stick.

Sighting is through an optical gun sight or auxiliary ring-and-bead sight. Electric heaters attached to each gun permit them to function at temperatures as low as −70°F.

A removable, streamlined bomb rack is provided on each outer wing panel for bombs up to 500 lb, depth charges, chemical or auxiliary fuel tanks.

Fusing of the bombs is electrically controlled from the cockpit, and bombs can be dropped in a dive, level flight, or 30-deg climb. Sway braces are integral with the racks.

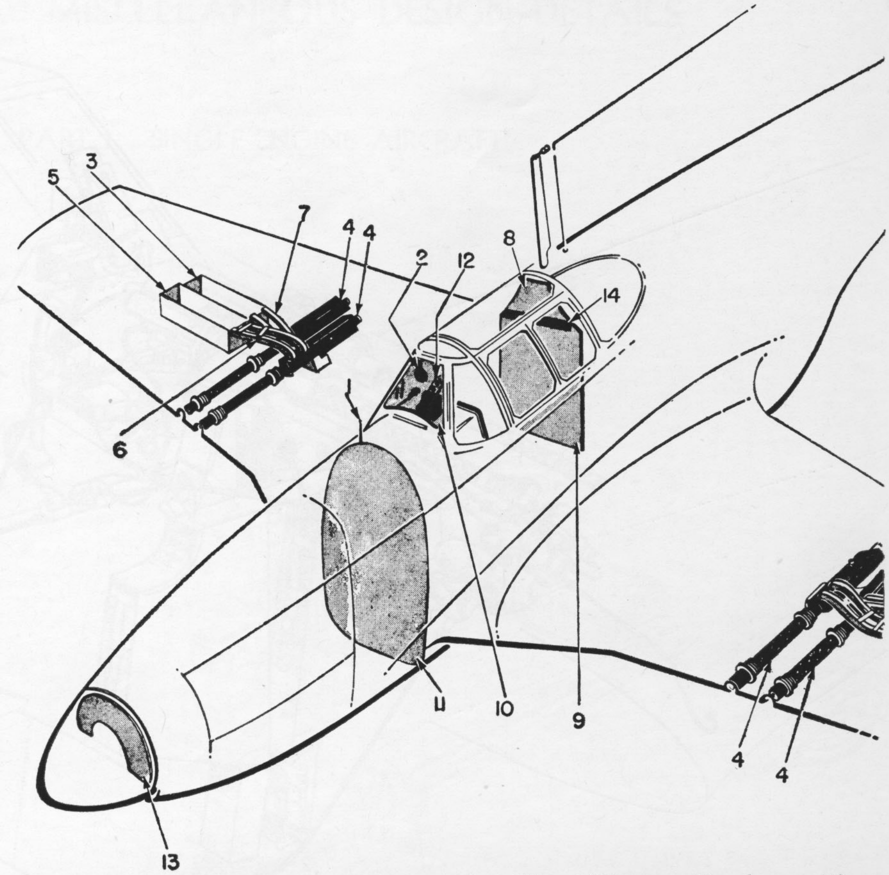


Fig. 1. Guns and armor: (1) and (2) ring sights; (3) and (5) ammunition boxes; (4) machine guns; (6) and (7) ammunition chutes; (8), (9), (11), and (13) armor plate; (10) bulletproof windshield; (12) optical gun sight; (14) detachable Plexiglas side panels.

Zeke 32 (Hamp)

Wing and fuselage flotation gear were provided in the Zeke 32, the wing gear formed by making watertight boxes. One was formed by the front spar, leading edge, and ribs 8 and 23; the other by the front and rear spars and ribs 8 and 22 (1). These are connected by tubes leading to the cockpit with a valve which can be closed in case of a forced water landing.

The fuselage gear consists simply of a canvas bag with a tube leading to a cockpit valve which also can be closed. Thus, the flotation gear consists of trapped air, the valve arrangement being necessary to accommodate varying pressures caused by changes in altitude.

The pilot's seat is equipped with an adjusting mechanism (2) which is attached to former *H*. A shock cord bungee going up over the pulleys tends to pull upward on a bracket—on

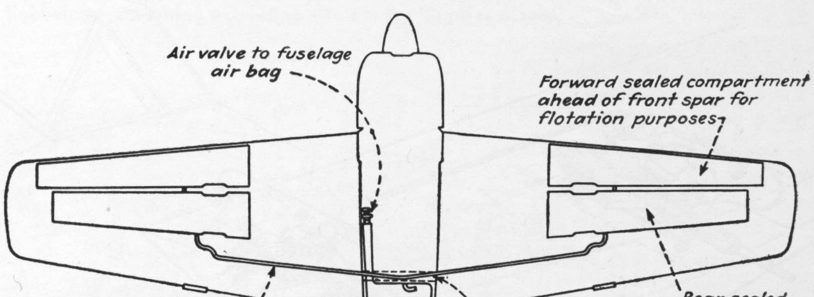


Fig. 1. Diagrammatic layout of the flotation gear.

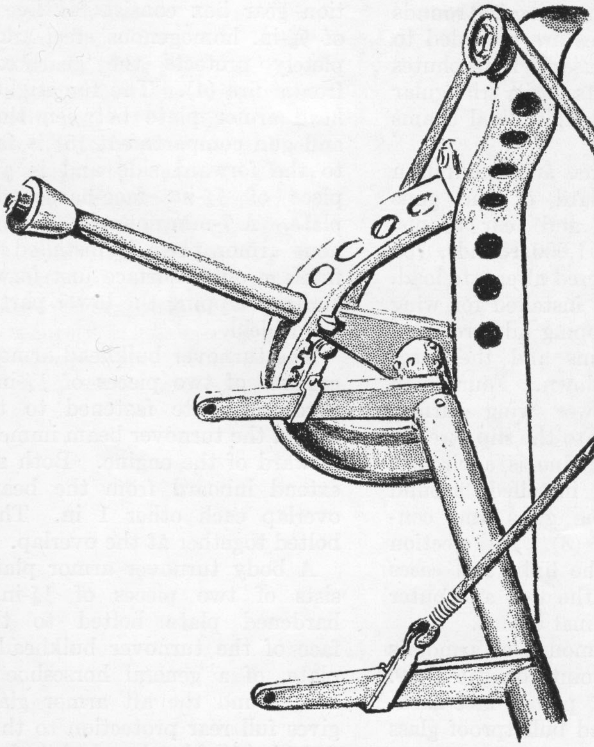


Fig. 2. Detail sketch of the adjusting mechanism of the pilot's seat.

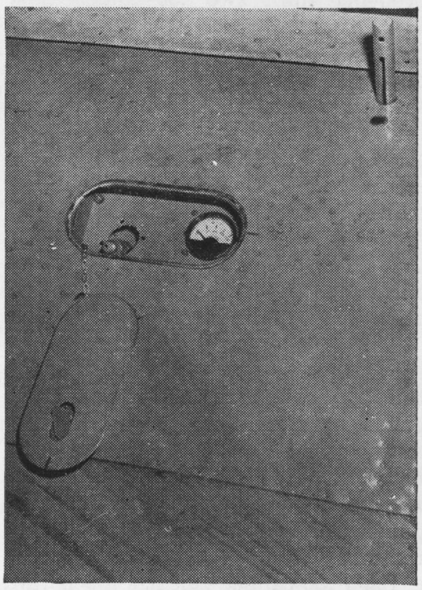


Fig. 3. Oxygen-supply connection and pressure gauge set in the left side of the fuselage just beneath a retractable handhold. The cover plate is quickly removable but chained to prevent loss; a red line on the end assures replacing in proper position. Although of light construction, this plate fits flush with the fuselage skin.

which the seat itself is attached—as the ratchet lever position is changed. The seat is adjustable only up and down; fore-and-aft adjustments are made on rudders.

The oxygen-supply connection and pressure gauge are set in the left side of the fuselage just beneath a retractable handhold (3). The cover plate is quickly removable but chained to prevent loss. The plate fits flush with the fuselage skin. Latches are used to fasten the cover plate to the oxygen-supply system (4). Although the Hamp has very few openings, most of them are of this quick-opening type.

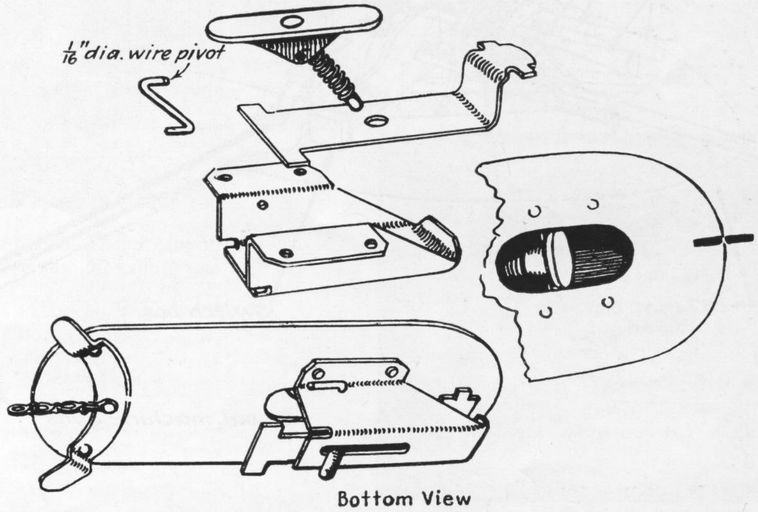


Fig. 4. Detail sketch showing the latches used to fasten the cover plate to the oxygen-supply system. The Hamp has very few openings, but most of them are of this quick-opening type.

Bell P-39 Airacobra

Armament of the P-39 consists of a 37-mm cannon located on the fuselage center line just above the extension drive shaft with the gun barrel projecting through the reduction gearbox and propeller hub; two .50-caliber type M-2 machine guns installed in the forward fuselage just ahead of the pilot and synchronized to fire through the propeller arc; four .30-caliber free-firing machine guns installed in pairs in each outer wing panel (1).

The cannon and machine guns are manually charged and electrically fired by solenoid units actuated by two firing switches on the control stick, one for the cannon and the other for the machine guns.

The .50's are equipped with flame-suppressor blast tubes. An impulse tube-type synchronizer is used on these guns, the tubes fabricated from chrome-moly steel and clamped to the gun barrels at about 12-in. intervals. Exhaust louvers are installed in the gun-compartment cowling to evacuate fumes.

Each .50-caliber gun has a separate ammunition case containing 200 rounds (2). Ejection chutes are provided to carry off links and cases. Both chutes deposit their contents into a triangular space between the longitudinal beams and outer skin.

Each set of .30's has an ammunition box located outboard of the guns between the front and rear beams. The boxes contain 1,000 rounds, 700 of which are considered alternate load. Ejection chutes are installed for wing guns, the links dropping inboard from their respective guns and the cases dropping straight down. Four small doors on each lower wing surface eject the contents into the slip stream.

The 37-mm magazine is a circular endless-belt type, installed around the frontal machine guns and containing 30 rounds (3). An ejection compartment for the links and cases is located between the web and outer skin of the longitudinal beams.

A considerable amount of armor is installed at vital points on the P-39. Homogenous steel plate, face-hardened steel plate, and bulletproof glass are used.

Armor plate at the propeller reduction gear box consists of five pieces of ⅝-in. homogenous steel and completely protects the gearbox from frontal fire (4). The fumetight bulkhead armor plate between the pilot and gun compartment (5) is fastened to the forward side and is a single piece of ⅝-in. face-hardened steel plate. A 7-mm nonmagnetic homogenous armor plate is installed on the fuselage outer surface just forward of and overlapping the lower part of the windshield.

The turnover bulkhead armor plate consists of two pieces of ¼-in. face-hardened plate fastened to the aft side of the turnover beam immediately forward of the engine. Both sections extend inboard from the beam and overlap each other 1 in. They are bolted together at the overlap.

A body turnover armor plate consists of two pieces of ¼-in. face-hardened plate bolted to the aft face of the turnover bulkhead. The plate, of a general horseshoe shape, fits around the aft armor glass and gives full rear protection to the pilot. A ¼-in. face-hardened plate is bolted to the bulkhead just aft of the oil

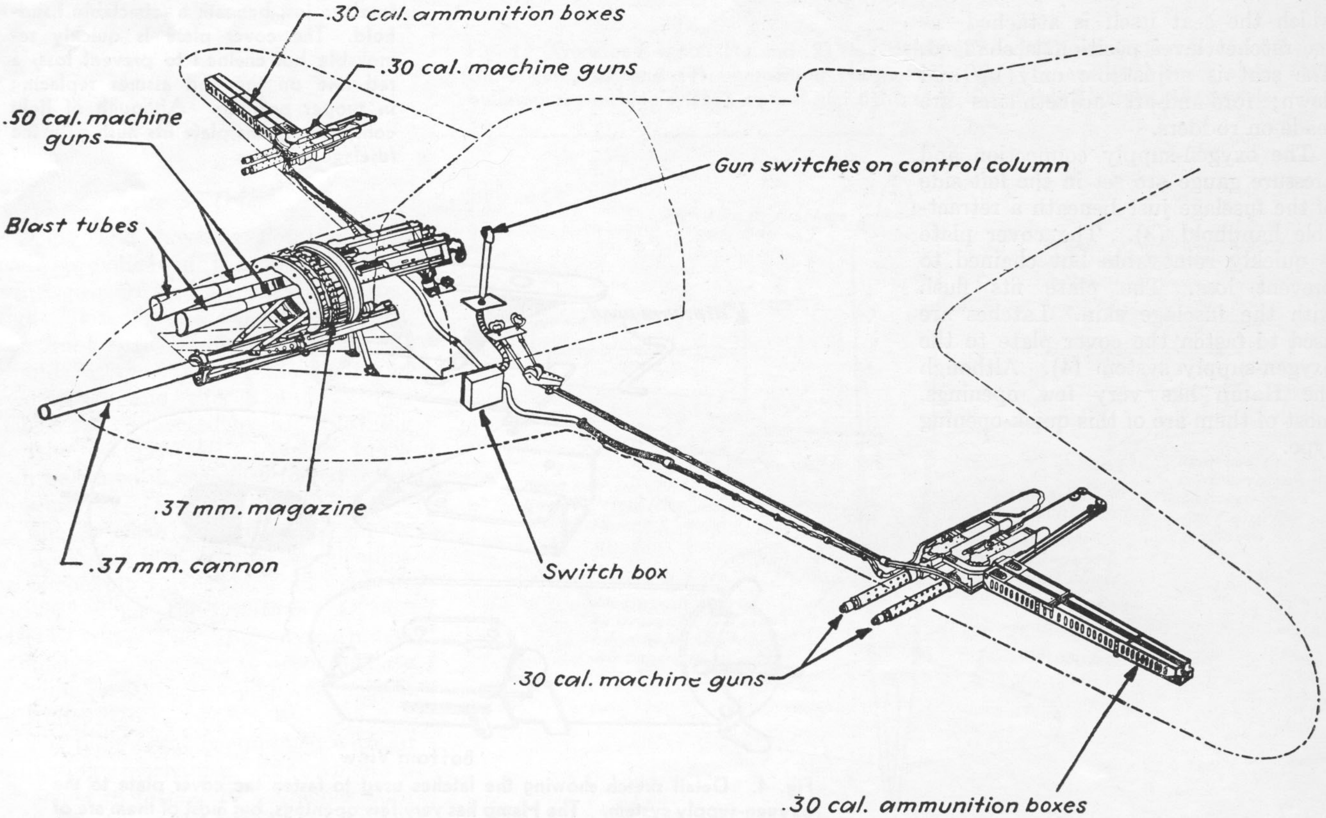


Fig. 1. General arrangement of the 37-mm cannon and .50- and .30-caliber machine guns, ammunition boxes, and controls.

tank and is designed to protect this tank.

Forward armor glass is 1½ in. thick and is located above and forward of the gun-sight support casting and at the top of the transverse windshield frame. In conjunction with the armor plate at the lower outside windshield, it protects the pilot from frontal fire.

The aft armor glass, also 2½ in. thick, is located in the curve of the fuselage turnover beam aft of the pilot. It is held securely in place by a jamb nut and dovetailed screw which fastens to the top inside curve of the turnover beam (5).

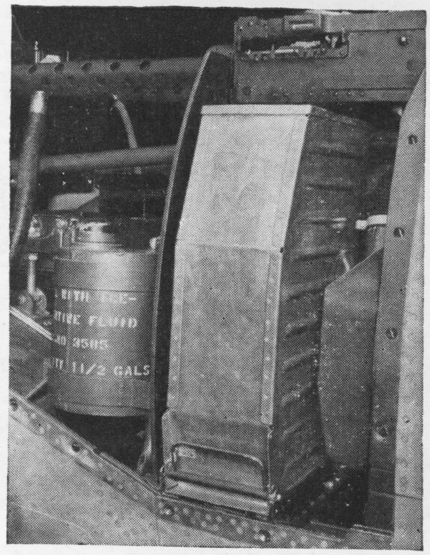


Fig. 2. Magazine boxes for ammunition for the .50-caliber guns, located just forward of the cabin bulkhead.

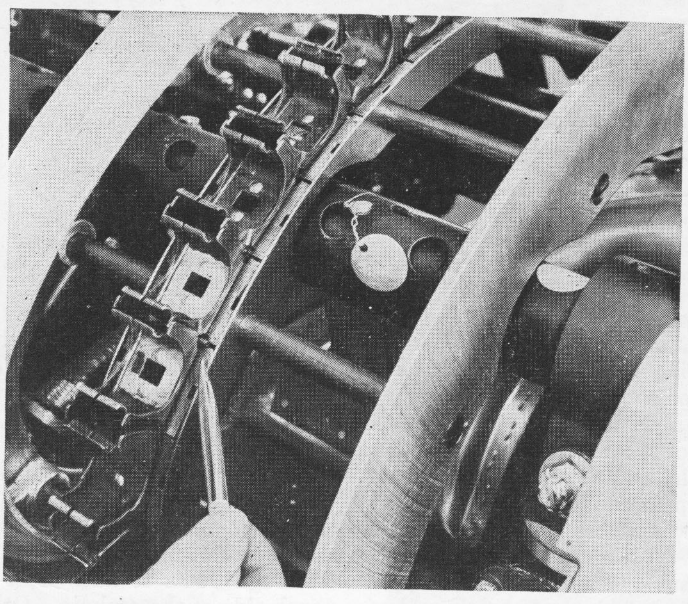


Fig. 3. The circular endless belt-type magazine for the 37-mm cannon has a capacity of 30 rounds and is located around the .50-caliber gun barrels. Shell clips are shown here in detail.

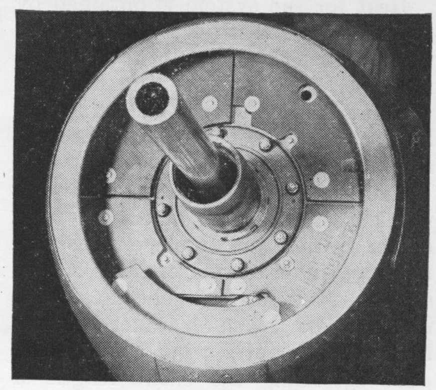


Fig. 4. Close-up of ⅝-in. homogenous steel armor-plate installation protecting the reduction gearbox.

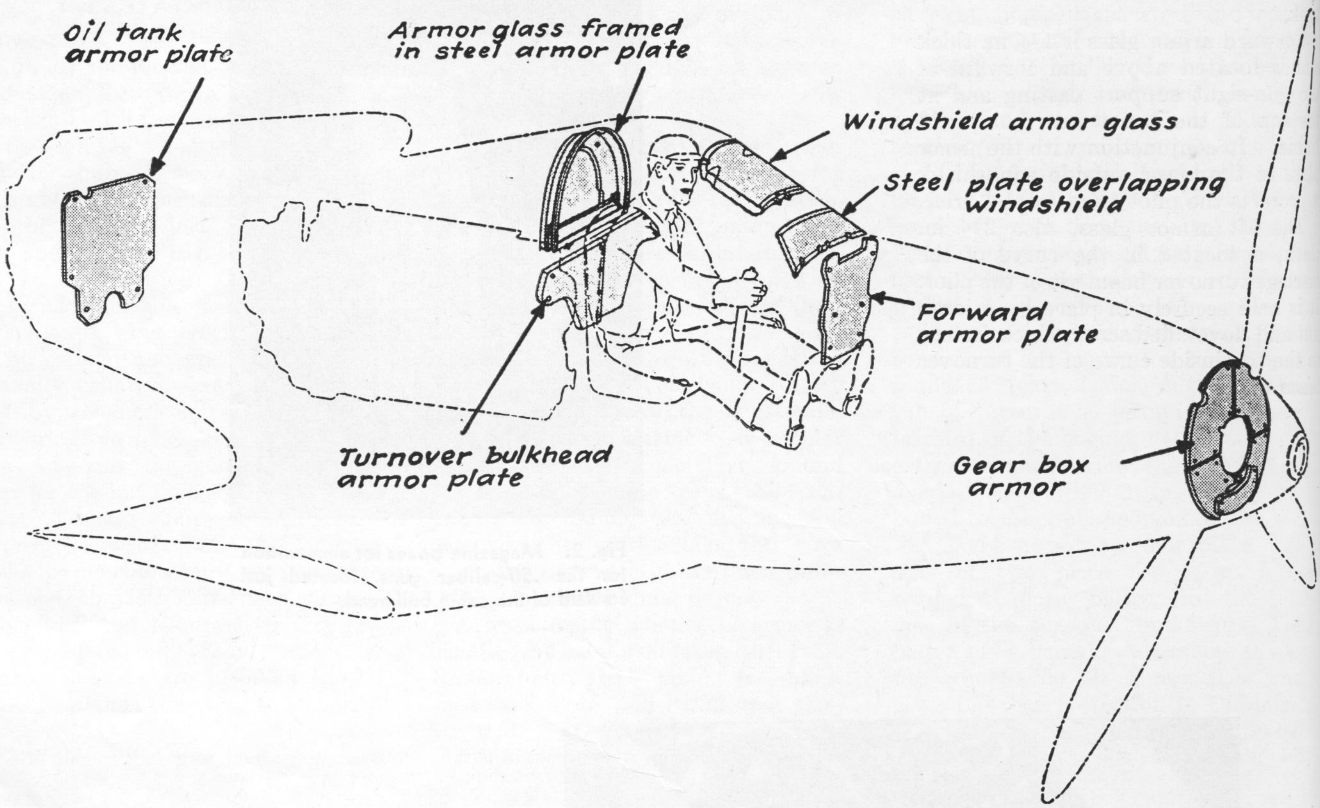


Fig. 5. Diagram showing the location and shape of the armor plate.

PART 2. MULTIENGINE AIRCRAFT

Fairchild C-82 Packet

The C-82's anti-icing system (1) protects all flight surfaces and air-intake scoops (carburetor, oil cooler, heating and ventilating, and anti-icing).

Heat for the system is obtained by passing rammed air from a scoop on the lower portion of each primary cowl through four crossflow-type heat exchangers located in the exhaust system between the collector rings and exhaust stacks.

Exchangers are connected by a trunk duct extending across the wing center section and fuselage, thus permitting functioning of the entire system even though one engine is inoperative. From this duct, another leads to the outer wing leading-edge duct extending the entire length of the outer panel and tip. After passing through the L.E. duct, the air dumps into the inner portion of the wing and exists on the L.E. of the ailerons. Center-wing section anti-icing is accomplished similarly.

From a main trunk within each boom, a duct leads to the empennage, and smaller ducts lead to the stabilizer tip and upper and lower fins. Heating of these surfaces is accomplished similarly to the outer wing panel, except that the air exits onto upper and lower outside surfaces through a series of small holes.

Windshield anti-icing is by hot air from the main trunk crossduct, and after dispersal between the double glass panels, the air is dumped outside the fuselage below the windshield.

The system for the crew and cargo compartments secures heated air from main trunk duct across the fuselage, supplied from the two inboard heat exchangers. The heated air, passed through a secondary heat exchanger in the fuselage to ensure freedom from carbon monoxide, is diverted through ducts to the cargo compartment and is circulated from 16 anemostat units located along each side of the fuselage, about 1 ft above the floor. Air for the cockpit is secured through a scoop on top of the cockpit (2) and is heated by passing through the secondary heat exchanger, then being distributed through ducts to anemostat units on each side of the cockpit. Other ducts bring in air for defogging the windows and navigation dome.

Ventilation is accomplished by introducing to the heating system variable amounts of cold outside air, with the proportion controlled by the crew.

The anti-icing, heating, and ventilating systems are electrically controlled from the switch panel above and between the pilot and copilot. Two switches permit selection of heat from all four exchangers for

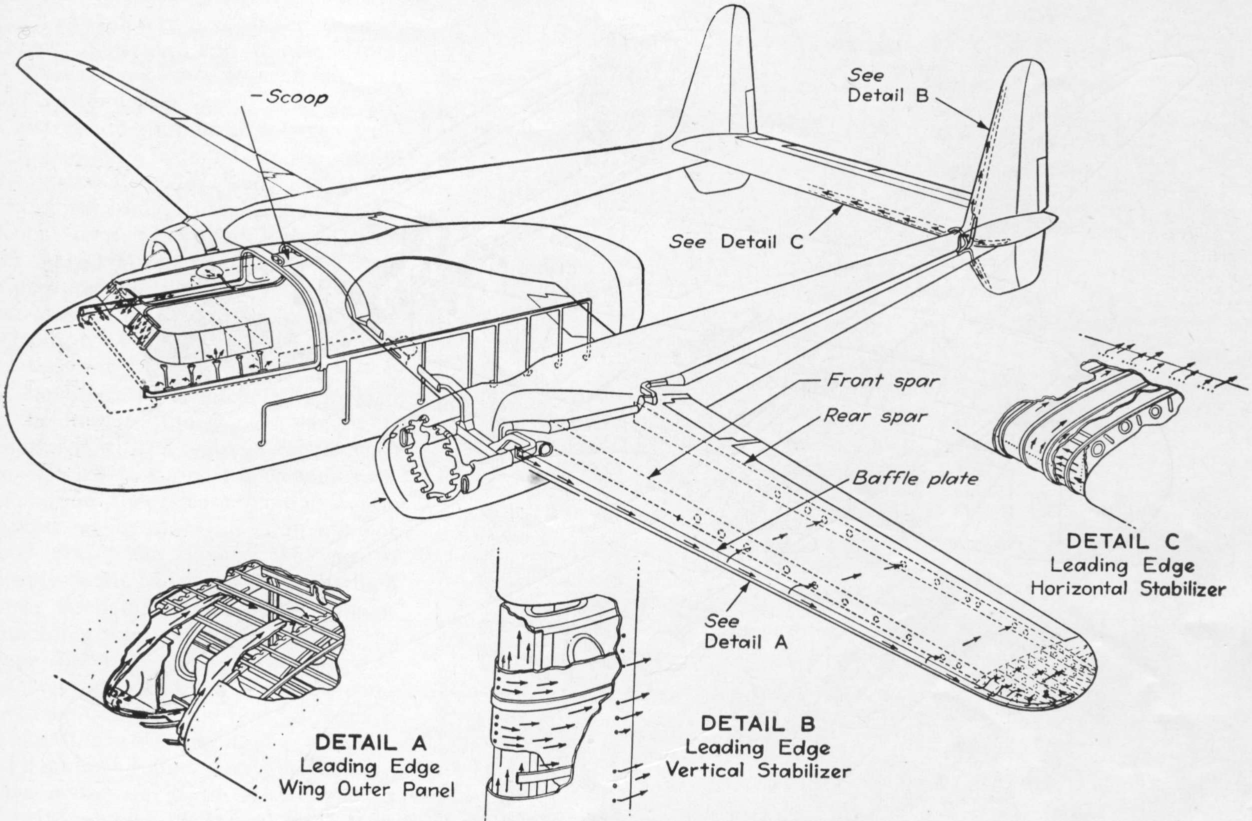


Fig. 1. General details of anti-icing and heating provisions.

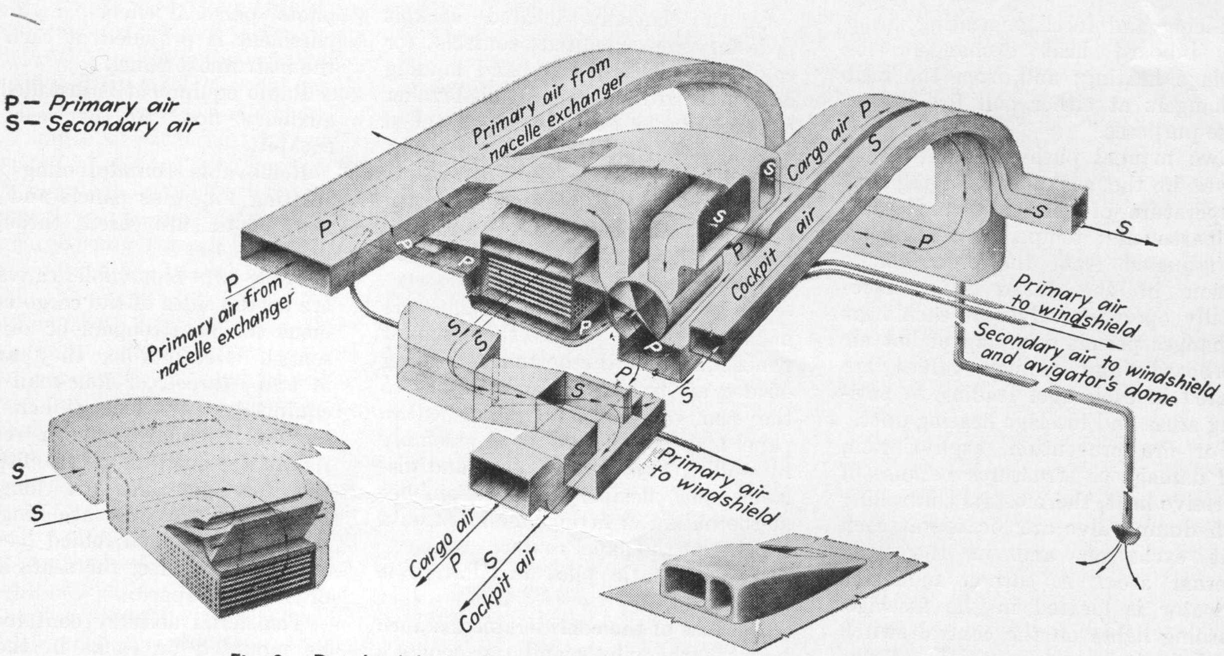


Fig. 2. Details of the fuselage scoop and secondary exchanger installation.

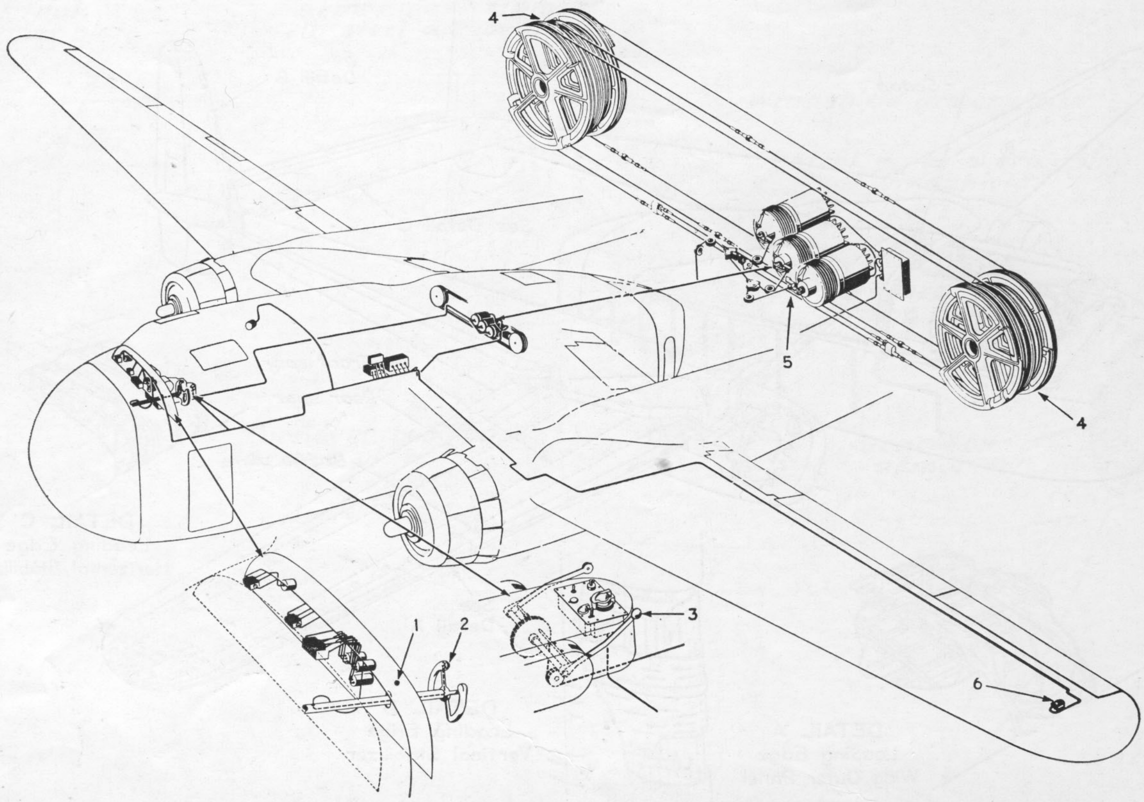


Fig. 3. A-10 automatic pilot installation: (1) location of automatic flight controller; (2) electric disengaging switch; (3) mechanical emergency disconnect; (4) sector wheels for aileron, elevator, and rudder systems; (5) servo units; (6) gyro-flux-gate transmitter.

anti-icing and fuselage heating; from two inboard heat exchangers for fuselage heating; and from the heat exchangers at either end for any of these purposes.

Two manual push-pull controls to valves in the cockpit ducts regulate temperature of the crew and cargo compartments; temperature also can be adjusted from the crew chief's station in the cargo area. Electrically operated valves at each heat exchanger permit dumping of hot air overboard, and similar valves are located in each duct leading to anti-icing areas and fuselage heating duct.

For fire prevention, asphyxiation, and damage to structures because of excessive heat, thermostats controlling each dump valve are located at each heat exchanger and in the wing internal area. A carbon monoxide indicator is located in the fuselage. Warning lights on the control switch panel indicate the position of the dump valves and presence of carbon monoxide.

On a centrally located cockpit pedestal are mounted controls for engine, propellers, tabs, and landing gear, and switch and circuit-breaker panels. Radio controls are installed on overhead panels in the cockpit center within reach of both pilots. Interphones, oxygen equipment, heated suit rheostats, map case, emergency ax, and first-aid kits are mounted on the cockpit side walls.

Flight and engine instruments are installed on a large shock-mount panel hinged at the bottom for tilting 45 deg aft to provide accessibility to the rear of the panel. The entire panel may be removed as an assembly by pulling two electric plugs and disconnecting flexible tube assemblies at the bulkhead fittings mounted on a bracket at the panel center.

An automatic pilot installation is included (3).

Because of the considerable distance between the pilot's and the copilot's seats, duplicate flight instruments are provided. For storage of the two pilots' personal effects, a glove compartment is provided at each end of the instrument panel.

Radio equipment is installed on the auxiliary floor to the rear of the cockpit.

Removable soundproofing and insulating Fiberglas panels and interior trim cloth are used through the fuselage.

Forty-two removable canvas seats are on the sides of the cargo compartment for paratroopers or other personnel. Retractable, they are built in two-, three-, or four-man sections equipped with safety belts. Each section is mounted on a rear tube rigidly fastened to clamp fittings on the fuselage outboard longitudinal beam, and seat legs are hinged to a front tube. When folded back along the fuselage sides, the seats are clear of the cargo space.

Ten aerial delivery containers may be mounted on racks in the center cargo section between the canvas seats (4).

As an ambulance plane, the Packet can accommodate 34 litter patients and 5 attendants; or 22 litter patients, 22 seat patients, and 3 attendants; or 13 litter patients, 40 seat patients, and 2 attendants.

Litters are supported between fixed wall brackets fastened to the cargo-compartment side, and suspension straps are hung from ceiling fittings. Loops (over which are lock fittings) are spaced 17 in. apart to form tiers of four or five litters. When not in use, suspension straps are folded from bottom to top and stowed in bags located in the ceiling.

The life-raft compartment, located in the fuselage upper rear section, is equipped with a canvas cinch with shock cords to support a six-man raft. A pull on the release handle in the cockpit releases the raft compartment door and then opens the carbon dioxide bottle to inflate the raft which forces itself out of the compartment. A mooring rope securing the raft to the plane prevents it from drifting too far before boarding. The raft compartment can be used as an escape hatch after raft ejection.

Pilot's and copilot's oxygen installations consist of type A-12 demand regulator, pressure gauge, flow indicator, mask, and duration graph. Each of the other crew members has a regulator, indicator, and mask.

For safety, the copilot's and navigator's demand-type oxygen regulators are manifolded to three G-1 oxygen cylinders; the pilot's, radio operator's, and crew chief's regulators are manifolded to five cylinders.

Two portable demand-type units are located in the cockpit, convenient to crew members. An additional portable unit is at the crew chief's station in the cargo compartment. Five portable rechargers are placed at various points in the plane.

For troops or litter patients, there is a continuous flow system supplied by four J-1 oxygen cylinders lashed to the floor in the forward cargo compartment and connected to the piping system by flexible hose. Since these cylinders are installed only when required, no permanent mounting cradles are provided.

Five continuous-flow regulators, located under the floor in the rear fuselage section, supply oxygen to 43 automatic coupling outlets strung along the side walls for the attachment of mask hoses.

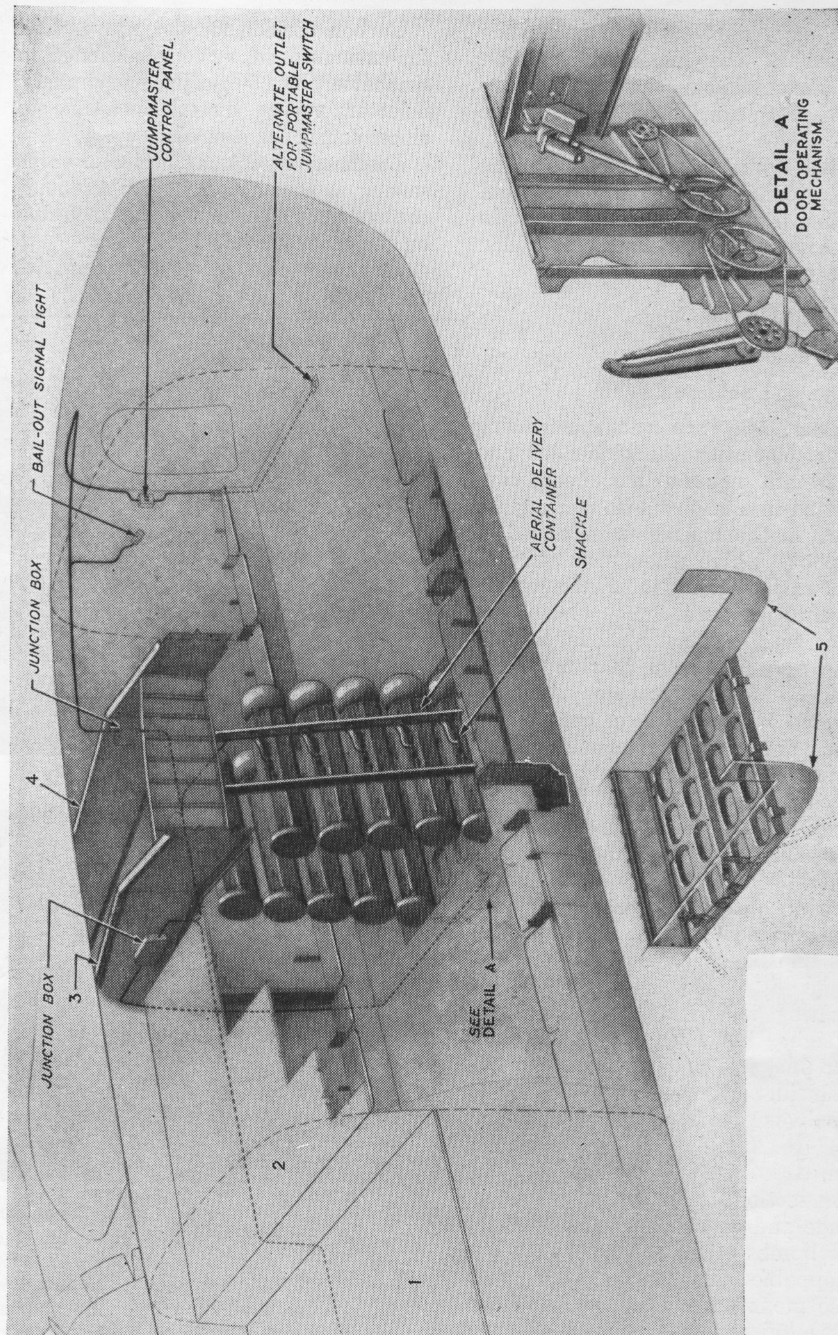


Fig. 4. Aerial delivery containers are shown here mounted on racks for dropping through doors seen at the bottom of the fuselage. Also depicted are: (1) cockpit floor; (2) accessory floor; (3) wing center section front spar; (4) rear spar; (5) main spar frames.

The oxygen filler valve is on the left side of the fuselage, accessible from the outside. Crew and troop systems both are filled from the same valve.

A line valve, accessible from the inside, separates the troop system filler line from the crew system; when the valve is open, both are filled simultaneously.

Carbon dioxide for the power-plant fire-extinguishing system is carried in six shatterproof 5-lb-capacity cylinders. Selector valves direct discharge to either engine, as desired.

Discharge of CO_2, and selector valve setting, is accomplished with solenoids controlled by selector switches mounted on the cockpit control pedestal.

In the engine power zone, nozzles located at the rear of the base of each cylinder discharge the gas in a fan-shaped pattern. In the accessory compartment, a perforated ring is used. Individual leads run to nozzles in the carburetor air-induction system blast tubes and the heat exchangers.

Lockheed P-38

In the P-38, armament consisting of four .50-caliber machine guns and one 20-mm cannon has been concentrated in a 20- by 8-in. rectangular pattern in the fuselage nose ahead of the pilot, where they fire straight ahead rather than in a converging fire from wing guns.

The gun compartment is located in the upper forward portion of the fuselage. Machine-gun ammunition is contained in four drawer-type trays. Cannon ammunition is provided from a drawer-type tray. Expended links and cartridge cases are discharged through chutes leading to openings in the skin below the armament compartment. Expended cannon-shell cases and links are discharged into a compartment between the bulkheads on the lower right side of the fuselage.

Sighting is by means of a Lynn gun sight, installed on the aircraft center line, just aft of the bulletproof windshield.

Bomb supports and type D-820 Interstate bomb shackles (1) are attached to the underside of the center section, midway between the fuselage and each boom. They carry either bombs of from 100 to 2,000 lb, or droppable fuel tanks.

Also mounted in the left drop-tank support fairing is a type M-6 gun camera. It may be operated independently or in conjunction with the guns.

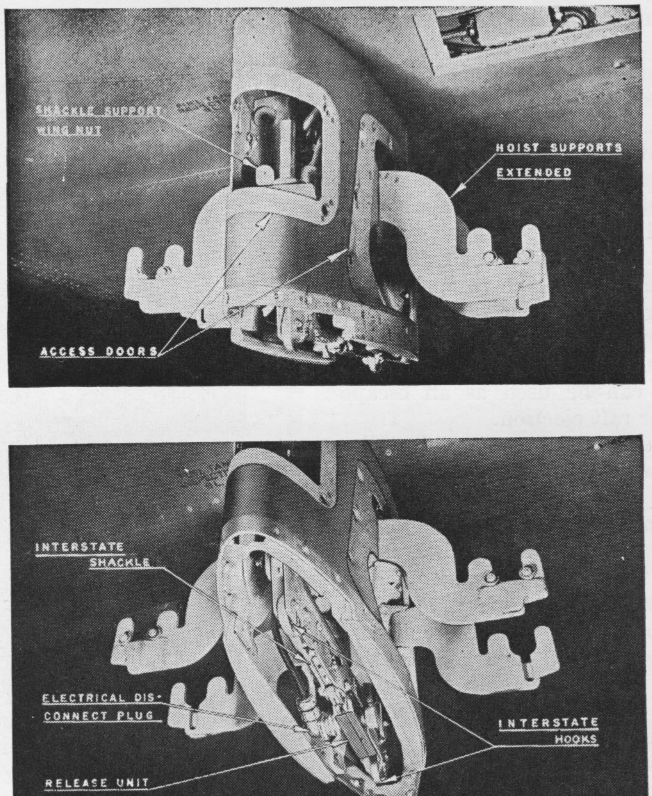


Fig. 1. Two views of the bomb or auxiliary fuel tank shackles, with front access doors removed. Located on each side of the fuselage inboard of the engines, these units support tanks which have given the P-38's range enough to be flown from the United States to England; from there to Africa and, consistently, as escort fighters covering heavy bombers on long-range attacks on Germany. Lightnings now carry two 2,000-lb bombs.

The armor plate consists of small pieces of face-hardened steel, attached separately to facilitate handling, removal, and replacement. The pilot is protected from frontal attack by armor plate mounted on the aft bulkhead of the armament compartment and by a bulletproof glass windshield. Two pieces of armor plate line the back and bottom of the pilot's seat, and a single piece of plate mounted behind and above the seat provides additional rearward protection.

Armor plate on the inboard sides of the superchargers, or circular deflectors on the superchargers, protect the pilot against possible fragmentation of turbosupercharger blades.

The photographic version, the F-5B, is a modification of the standard P-38J. The armament compartment is redesigned to accommodate any one of four arrangements of aerial cameras (2). Combinations of type K-18 with 24-in. lens cone and type K-17 with 6-, 12-, or 24-in. lens cone are used in each arrangement. The cameras are remotely operated by a type A-1 electrical control, and the camera lens apertures are controlled by a remote diaphragm control.

A Sperry type A-4 gyro pilot provides automatic control of the direc-

tion and attitude of the camera ship in flight.

The control units, which are mounted in the lower center of the instrument panel, give the pilot a visual check on the operation of the automatic pilot at all times, in addition to serving as flight instruments when the automatic pilot is not in use. It uses the plane's vacuum and hydraulic systems as power sources for its operation.

The furnishings include, in addition to pilot's seat, a flare pistol, glare shield, and other standard items, a rearview mirror fastened to the front portion of the top hatch, a demand oxygen system, and a cockpit heating system.

Cockpit heating is by hot air, the intensifier tube in both engine exhaust manifolds being ducted into the cockpit and directed on the pilot's feet. A flexible defroster tube may be used to defrost the top of the canopy.

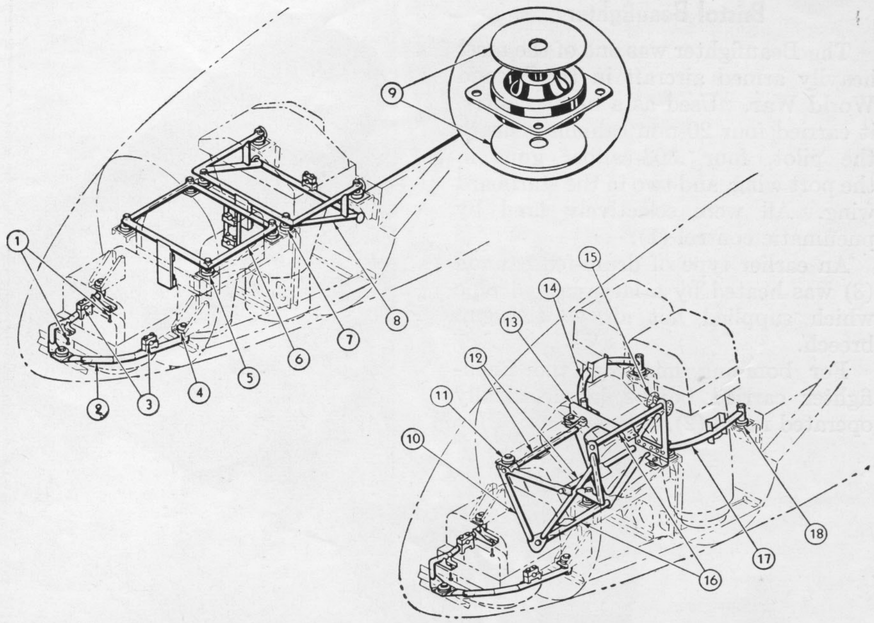


Fig. 2. Phantom view of the camera installation on F-5B photographic version showing (1) camera setscrews: (2), (6), (8), (14), and (17) cradles, (4), (5), (7), (11), and (18) Lord mounts; (9) bumper washers; (10) and (13) truss assemblies; (12), (15), and (16) supports; (3) caps on cradles.

Messerschmitt Me-262

The Me-262's radio is usual German equipment, FuG 16Z or FuG 16 ZY (VHF R/T, D/F, and retransmission facilities for ground control stations), and in some cases 1FF has been installed.

When the Germans capitulated in May, 1945, a final modification of the craft was in the works—the Me-262 B2— a two-man, radar-equipped night fighter. The principal changes necessary were made in the cockpit, where the pilot's seat was pushed forward slightly to help make room for the addition of the radar operator's screens and seat immediately behind. This, of course, meant changing the design of the canopy to give the necessary length, and relocation of the aft fuel tank, normal radio equipment, oxygen bottles, and master compass, all of which were pushed farther aft in the fuselage.

Since the 262 was not the most maneuverable plane to begin with, it is believed that the radar-loaded version was not so good a combat craft as the original day-fighter version.

The complete nose section is attached to the aft-gun-compartment bulkhead at four points (1).

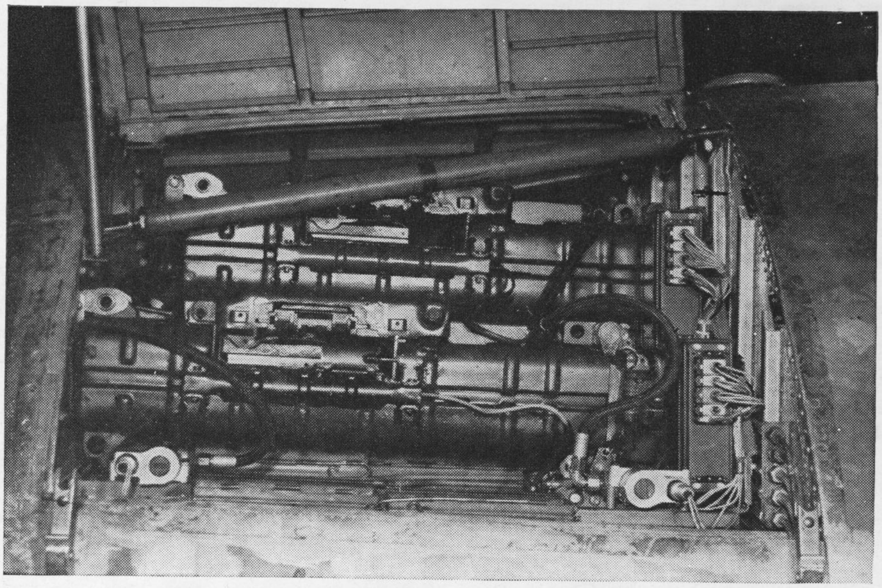


Fig. 1. Close-up of the left gun compartment, showing the access panel in raised position. Note the turnbuckle tie rod at the top; it makes one of four points at which the complete nose section is attached to the bulkhead at the right.

Bristol Beaufighter

The Beaufighter was one of the most heavily armed aircraft in the Second World War. Used as a night fighter, it carried four 20-mm cannon beneath the pilot, four .303-caliber guns in the port wing, and two in the starboard wing. All were selectively fired by pneumatic control (1).

An earlier type of drum-fed cannon (3) was heated by a large lagged pipe which supplied hot air to the gun breech.

For bombing missions, the Beaufighter carried bombs in electrically operated racks (2).

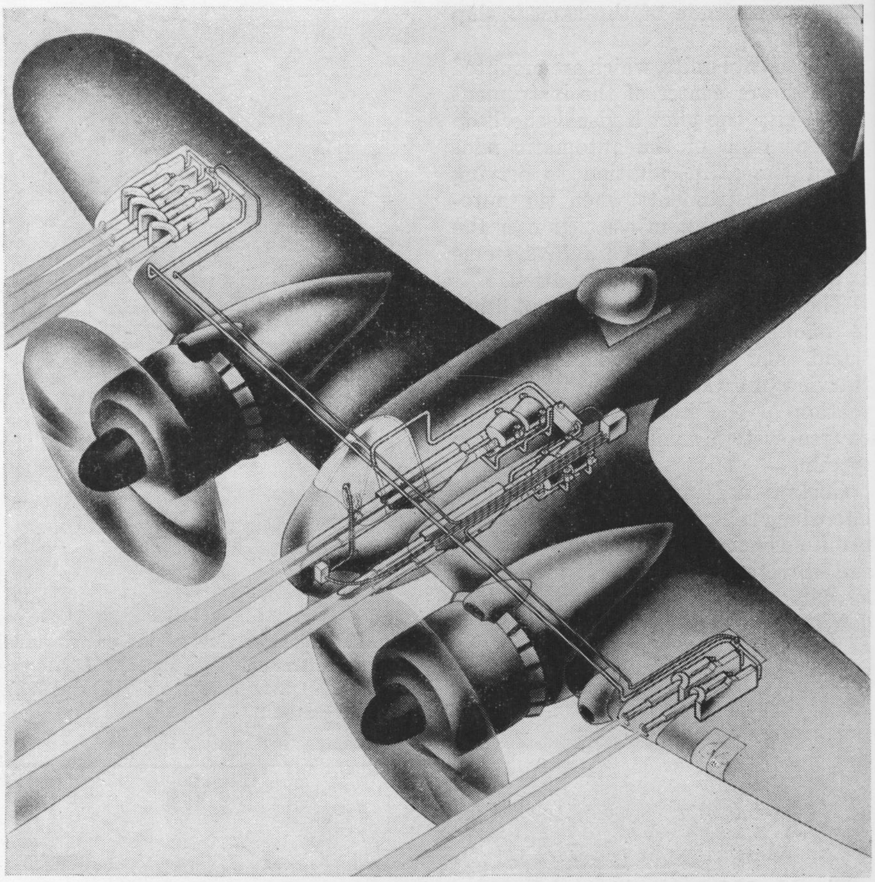


Fig. 1. Fire-power diagram of the Beaufighter showing four 20-mm cannon beneath the pilot, two .303 machine guns in the right wing, and four of the same caliber in the left. All are fired selectively by pneumatic control.

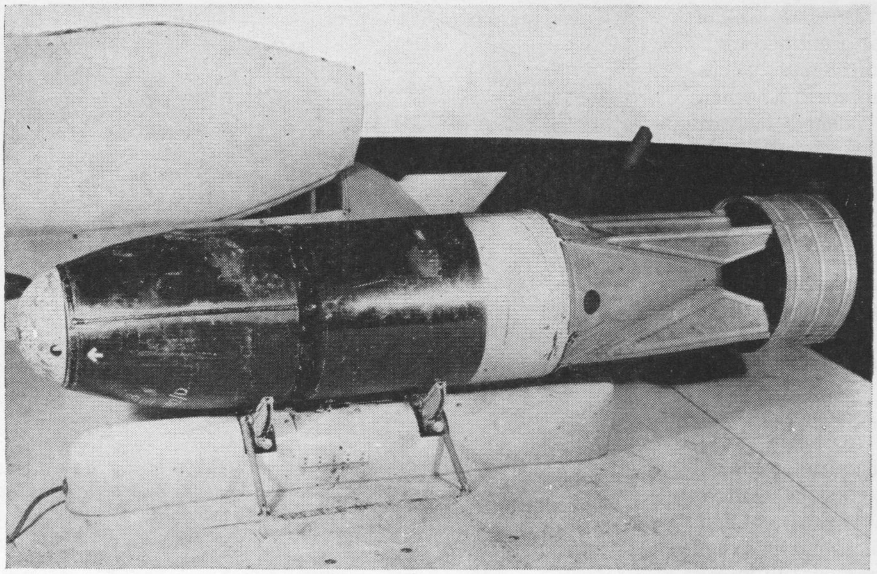


Fig. 2. A bomb in the electrically operated rack on a bomb-carrying Beaufighter.

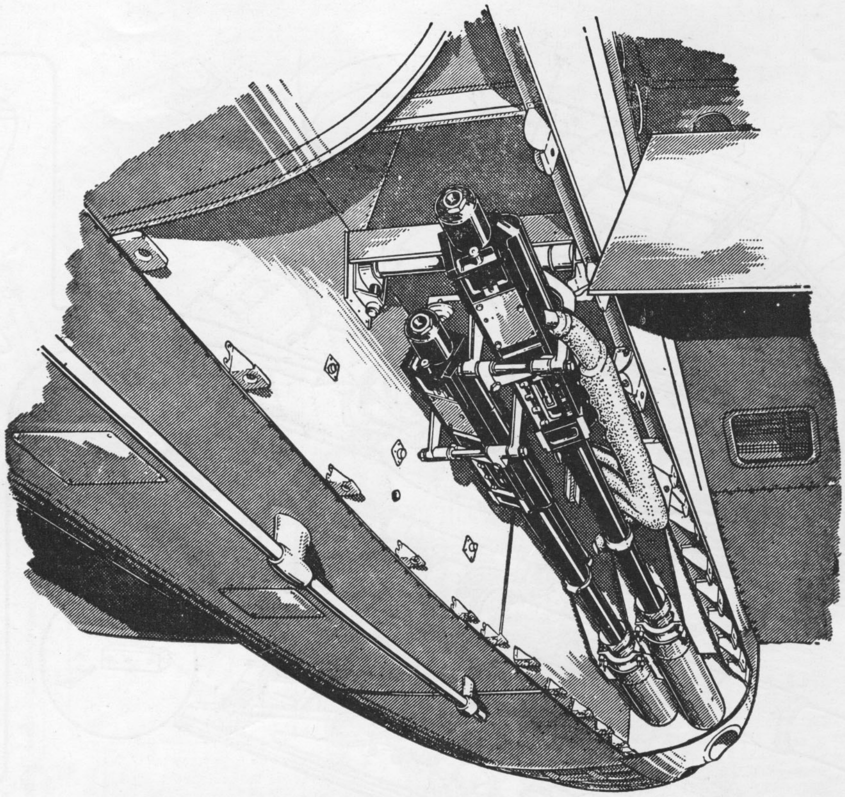


Fig. 3. Mounting of an earlier type of drum-fed cannon under the side of the nacelle. A large lagged pipe supplies hot air to the gun breech.

North American B-25 Mitchell

The radio system of the B-25 consists of the command set used for plane-to-plane communication, radio compass receiver, multiplace interphone system, and emergency transmitter for use in the life raft should the crew be forced down at sea.

The B-25J has a liaison set for long-distance plane-to-base operation as additional equipment.

The command set includes a rack with two transmitters, rack with three receivers, a combined dynamotor power supply and modulator, an antenna relay, and the necessary command radio wiring.

With the exception of control boxes, the command set is located in the upper left forward portion of the cannoneer's compartment on the B-25H, and in the upper turret gunner's compartment on the model J.

The radio compass consists of a receiver, remote-control box, azimuth indicator, rotatable loop, and terminal junction box. The receiver unit is a 15-tube superheterodyne with a wide frequency range and is located on the forward portion of the cockpit floor, on the right side of the plane.

The emergency transmitter, consisting of a portable unit with a self-contained generator, 300-ft antenna, kite, balloon, signal lamp, hydrogen generator, and parachute attached to two canvas bags in which the equipment is stowed, is used by personnel forced down in the water and is pre-turned to the international distress frequency of 500 kc.

Interphone equipment includes an amplifier, one jack box for each of the seven stations, and a throat microphone and headset for each crew member.

The liaison set consists of a receiver and transmitter.

The B-25H is armed with fourteen .50-caliber guns and one 75-mm cannon, while the model J mounts twelve .50-caliber machine guns.

The cannon assembly in the B-25H (1), consisting of a type T-13 weapon mounted on type T-13E2 recoil mount, is situated in the tunnel beneath the left side of the cockpit. The cannon muzzle projects forward through a blast tube in the lower nose section, and the breech extends aft to the left forward side of the cannoneer's compartment. The cannoneer loads the gun and the pilot fires it.

The all-metal nose forms the compartment for the four nose guns and ammunition boxes (2). The upper portion of the nose is hinged to provide access to the guns and ammunition belts. Guns are mounted side by side, are charged by the cannoneer, and are fired by the pilot.

Two guns are installed on each side of the fuselage just outside the cannoneer's compartment. Attached to metal brackets, they are enclosed by metal blisters fastened to the fuselage (3). Ammunition boxes are supported on a shelf structure at each side of the cannoneer's compartment. Blister guns also are fired by the pilot.

The upper turret (5) is installed on a support pedestal in the aft portion of the cannoneer's compartment. The field of fire of the two .50's in azimuth and elevation is automatically controlled by cams and switches in series, allowing the gunner to follow a target freely without the bullets striking any part of the plane.

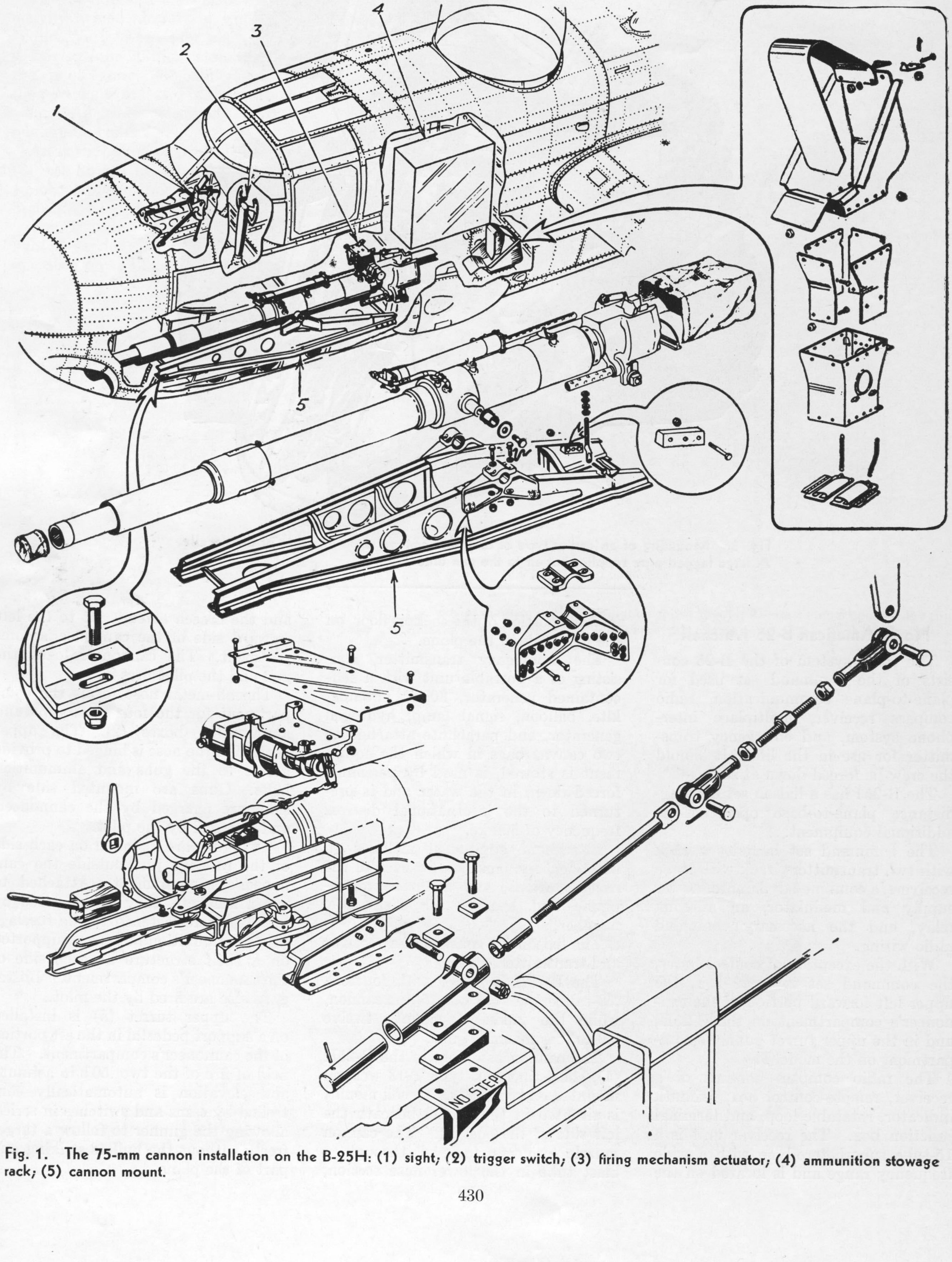


Fig. 1. The 75-mm cannon installation on the B-25H: (1) sight; (2) trigger switch; (3) firing mechanism actuator; (4) ammunition stowage rack; (5) cannon mount.

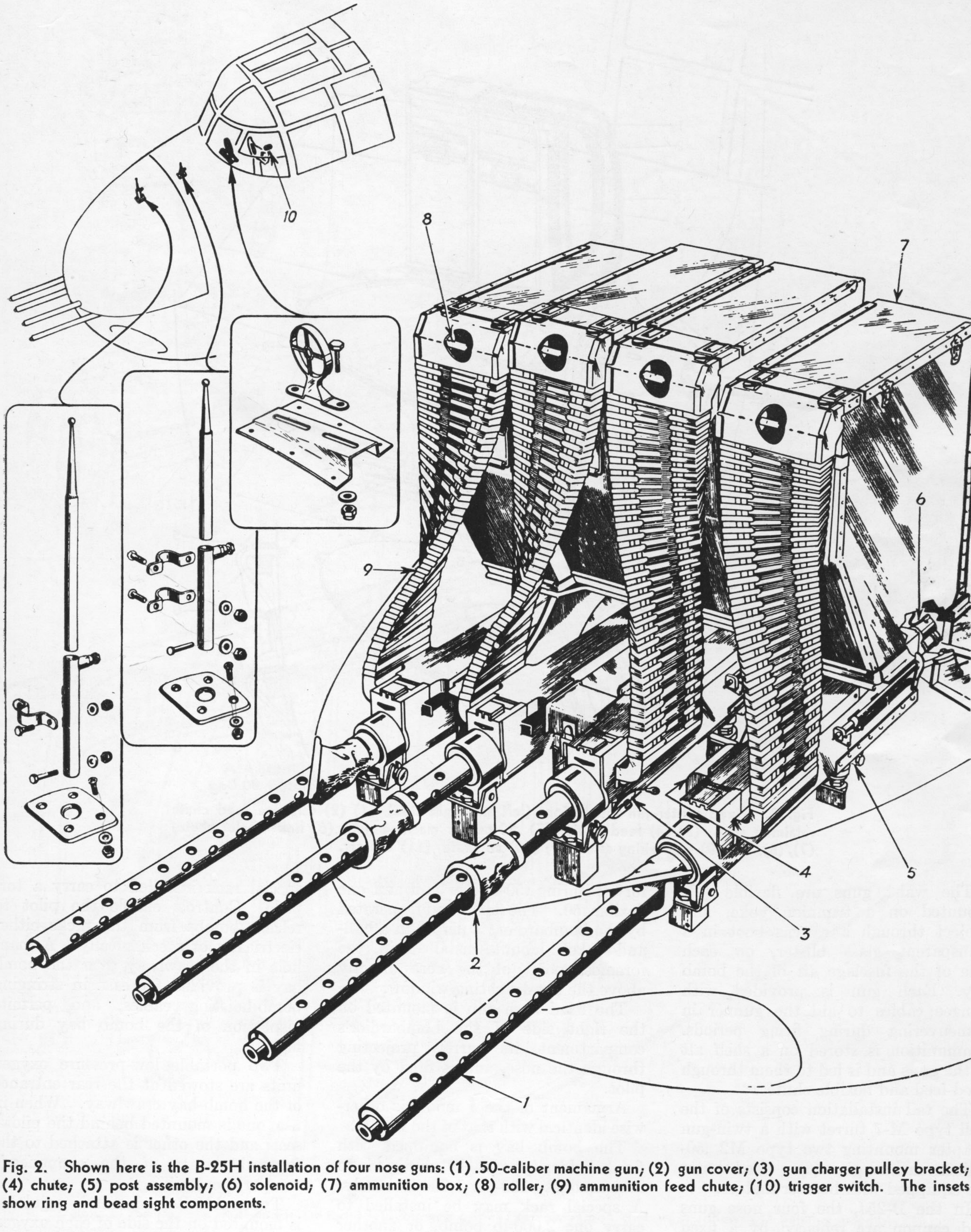


Fig. 2. Shown here is the B-25H installation of four nose guns: (1) .50-caliber machine gun; (2) gun cover; (3) gun charger pulley bracket; (4) chute; (5) post assembly; (6) solenoid; (7) ammunition box; (8) roller; (9) ammunition feed chute; (10) trigger switch. The insets show ring and bead sight components.

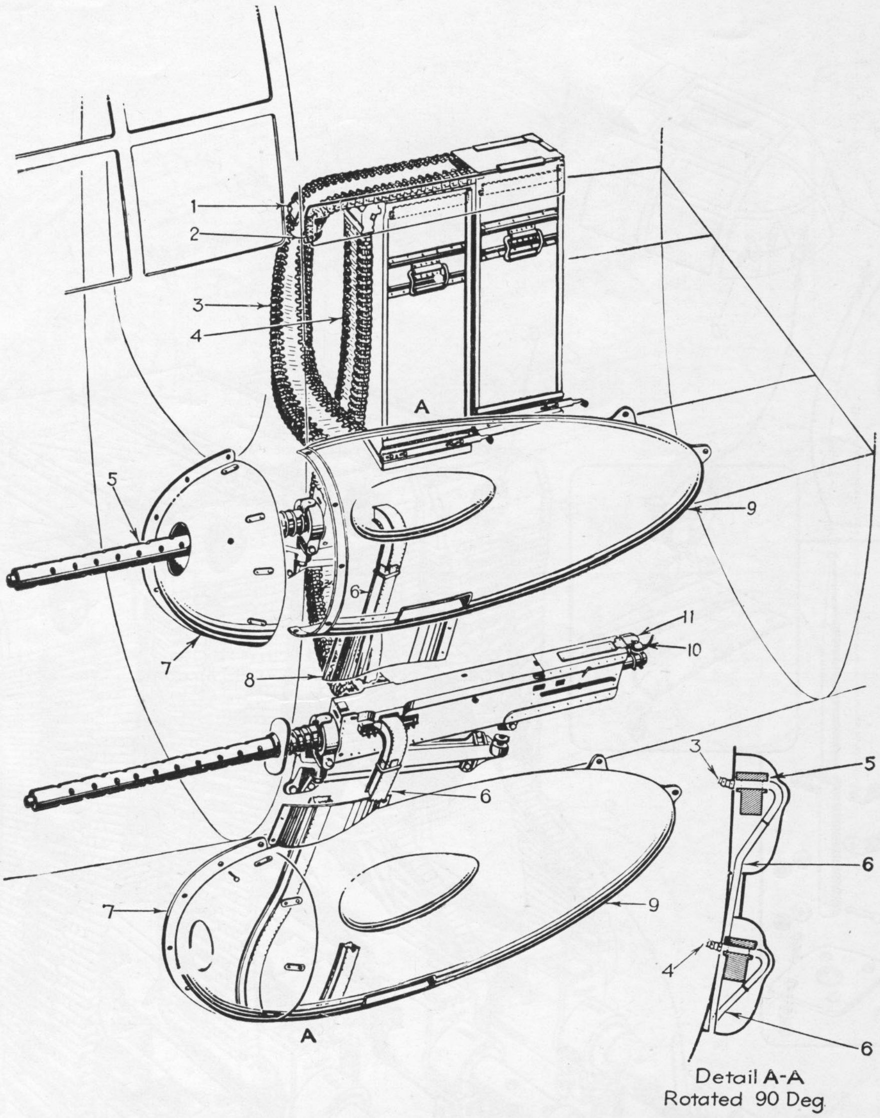


Fig. 3. Fixed blister-gun installations (left and right side): (1) (2) cartridge feed chute retaining strap; (3) (4) feed chute; (5) .50-caliber machine gun; (6) link ejector chute; (7), (8), and (9) gun fairing assembly; (10) solenoid; (11) charger.

The waist guns are flexible (4), mounted on a trunnion yoke, and project through a canvas boot in a transparent glass blister, on each side of the fuselage aft of the bomb bay. Each gun is provided with bungee cables to aid the gunner in maneuvering during firing periods. Ammunition is stored on a shelf aft of the guns and is led to them through fixed-feed and flexible chutes.

The tail installation consists of the Bell type M-7 turret with a twin-gun adapter mounting two type M2 .50-caliber machine guns (6). Feed chutes are equipped with booster motors.

In the B-25J, the four nose guns and cannon are replaced by a fixed forward-firing .50-caliber gun and one flexible .50. The flexible gun, operated by the bombardier, is placed in a ball-and-socket mount installed in the foremost point of the nose directly above the bombsighting window.

The fixed nose gun is mounted on the right side of the bombardier's compartment, its barrels projecting through the nose, and is fired by the pilot.

Armament of the J model is otherwise identical with that of the B-25H.

The bomb bay is equipped with fixed ladder-type racks designed to accommodate 100- to 1,600-lb bombs. A special rack may be installed to carry one 2,000-lb bomb, or another special rack installed to carry a torpedo. Controls enable the pilot to release bombs from the racks either electrically or mechanically. A manhole in the crawlway over the bomb bay is provided for ease in stringing bomb-hoisting cables, and permits inspection of the bomb bay during flight.

Two portable low-pressure oxygen units are stowed at the rear entrance of the bomb-bay crawlway. When in use, one is mounted behind the pilot's seat, and the other is attached to the forward corner of the cannoneer's compartment ceiling.

Type AN-R-5 demand regulator is mounted on the side of each oxygen

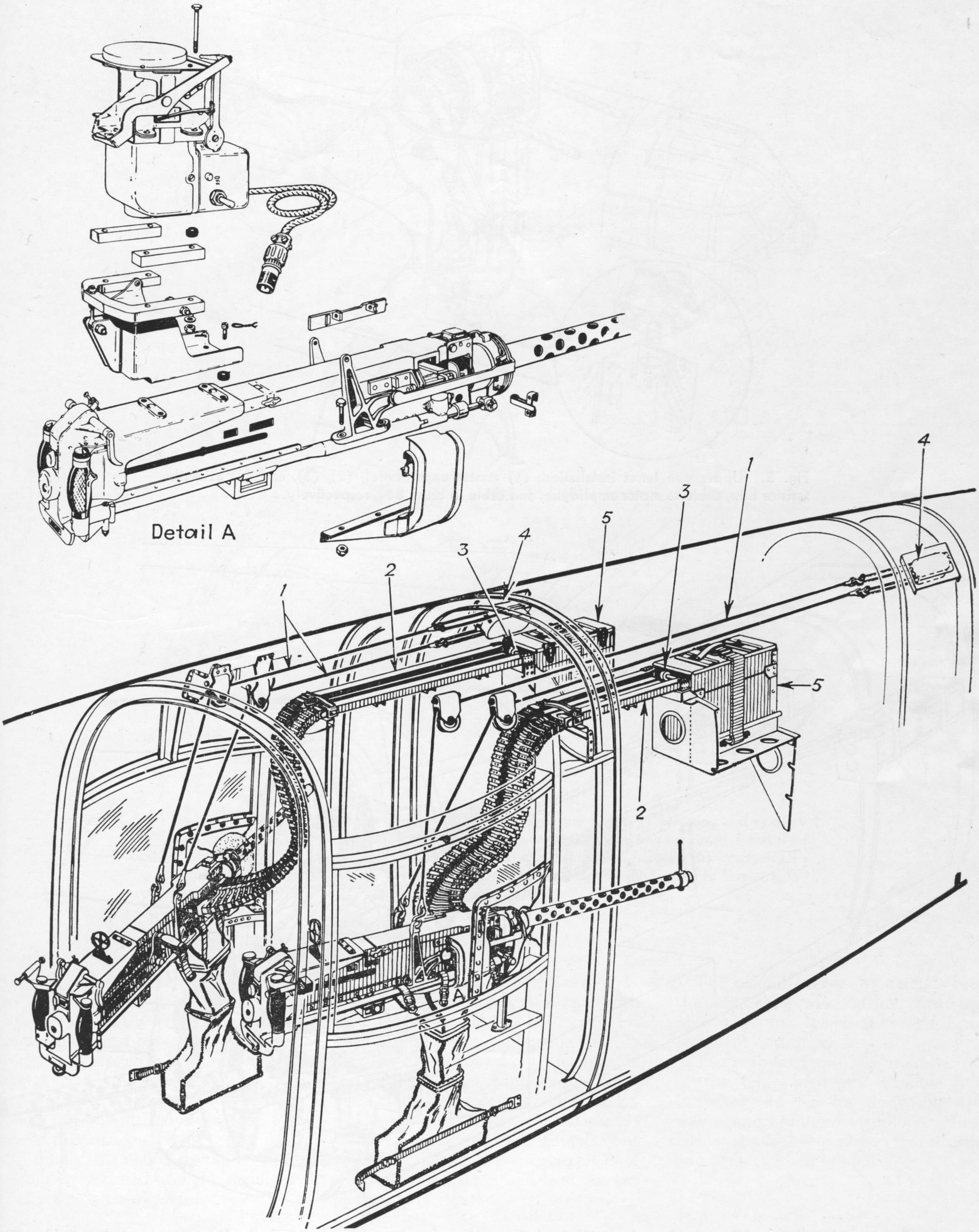


Fig. 4. Details of the flexible waist-gun installations: (1) bungee cable; (2) ammunition chute; (3) rollers; (4) balance assembly; (5) ammunition boxes.

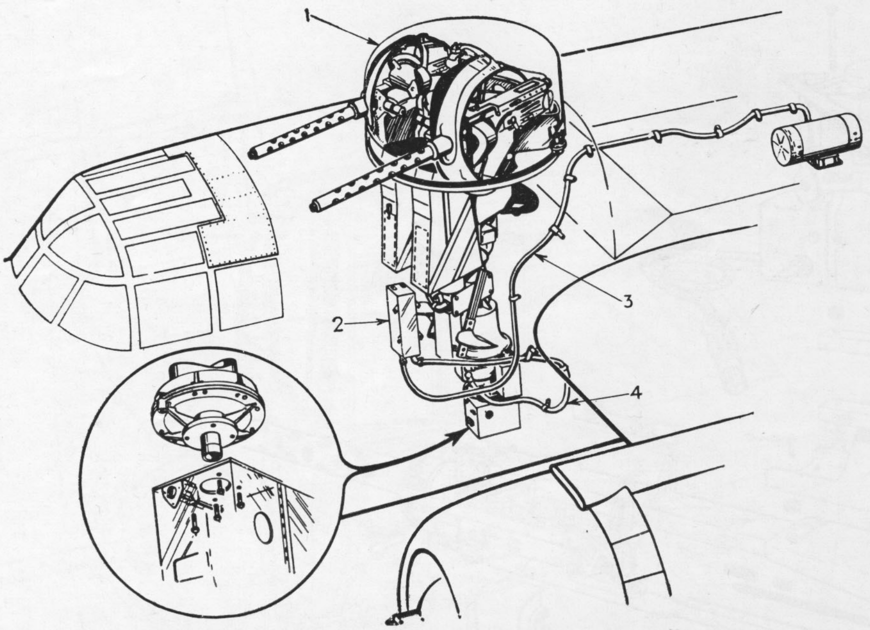


Fig. 5. Upper gun turret installation: (1) master upper turret; (2), (3), and (4) azimuth resistor box, cable to motor amplidyne, and cable to brush box, respectively.

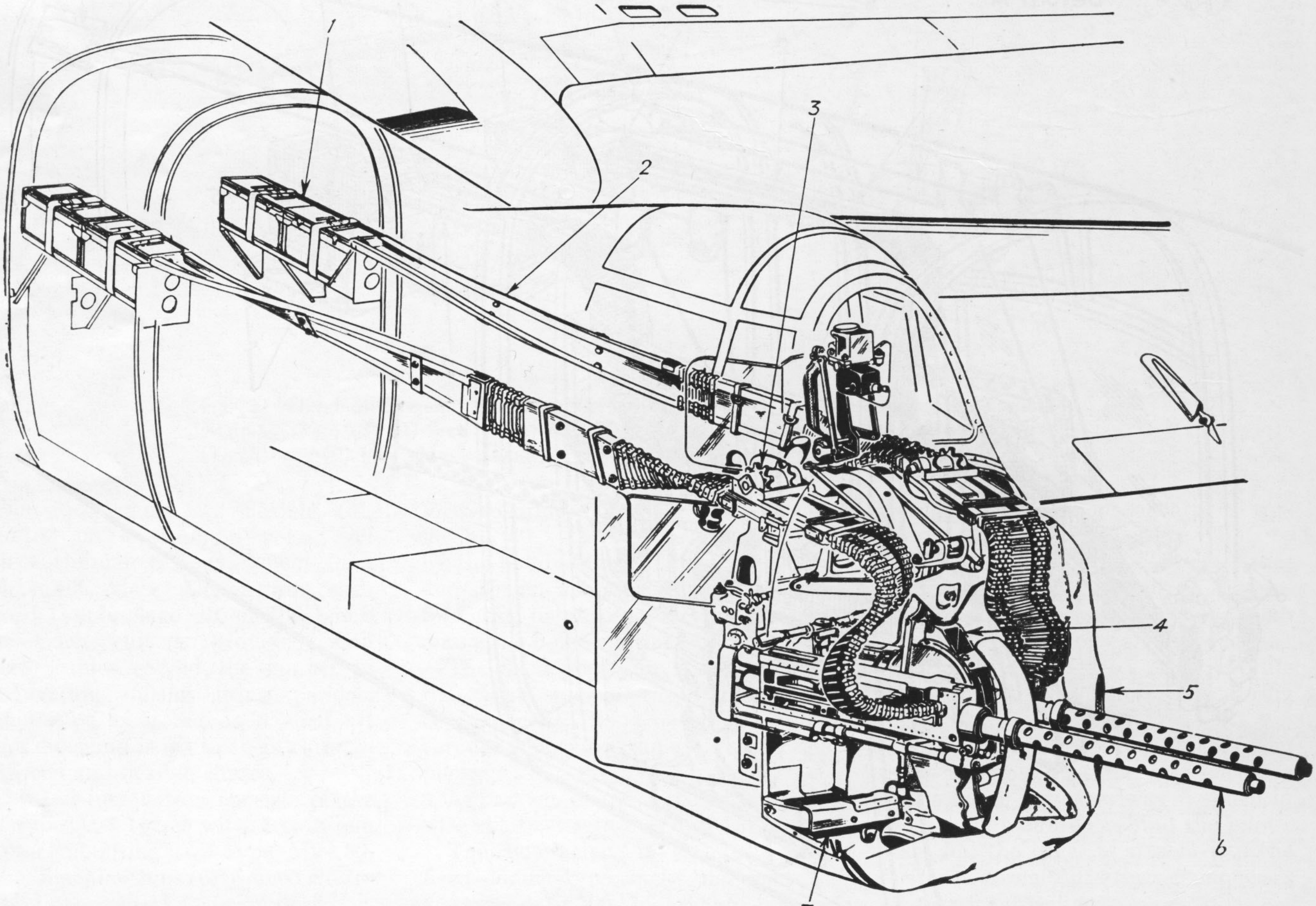


Fig. 6. Tail turret installation: (1) ammunition box; (2) feed chute; (3) ammunition booster; (4) hydraulic remote control assembly; (5) tail turret curtain; (6) .50-caliber machine gun; (7) ejected ammunition case deflector.

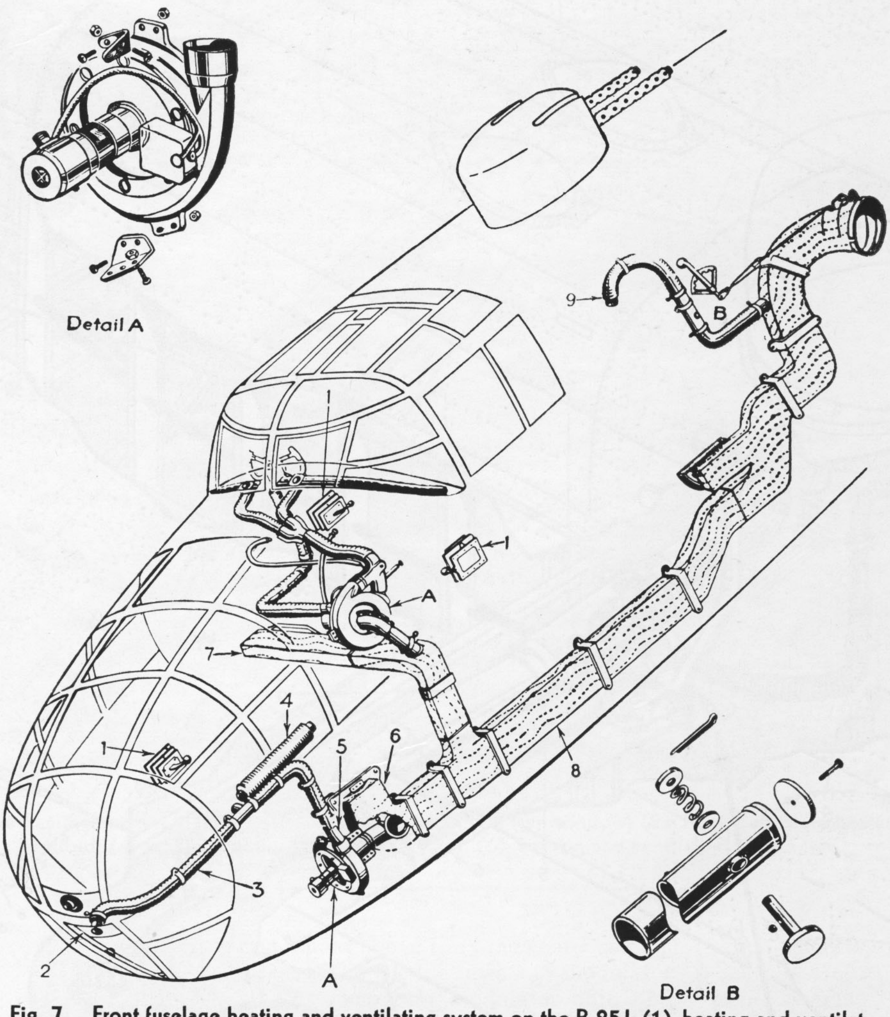


Fig. 7. Front fuselage heating and ventilating system on the B-25J: (1) heating and ventilating control; (2) bombardier's deicer panel; (3) heating and ventilating tube; (4) bombsight heating, ventilating, and defroster tube; (5) blower to flexible tube adapter; (6) bombardier's heating and ventilating outlet; (7) pilot's compartment duct; (8) duct, wing to fuselage, (9) turret compartment auxiliary defroster.

cylinder and automatically controls the flow and dilution of oxygen. Oxygen then mixes with free air in an amount governed by an aneroid valve which controls an air port and an oxygen port. At sea level the air port is open and the oxygen port closed. As the altitude increases, the aneroid expands and closes the air port until finally, at 30,000 ft, the air port is completely closed and the regulator is delivering pure oxygen.

Three interchangeable Stewart-Warner fuel-air heaters are used, each with an output of 50,000 Btu per hr. Ventilating and combustion air is supplied by a ram from openings in the cannon tunnel, wing leading edge, and external air scoops in the fuselage.

The forward heater (7) is located aft of the nose guns and supplies hot air for defrosting transparent areas of the pilot's enclosure, and heat for the pilots and navigator.

The second heater (8) extends into the left center wing section and supplies heat for the cannoneer's compartment and upper turret.

The rear heater (9) is mounted aft of the left waist gun window and furnishes hot air for defrosting the waist and tail-gun windows. Provisions have been made for electric gun heaters when needed.

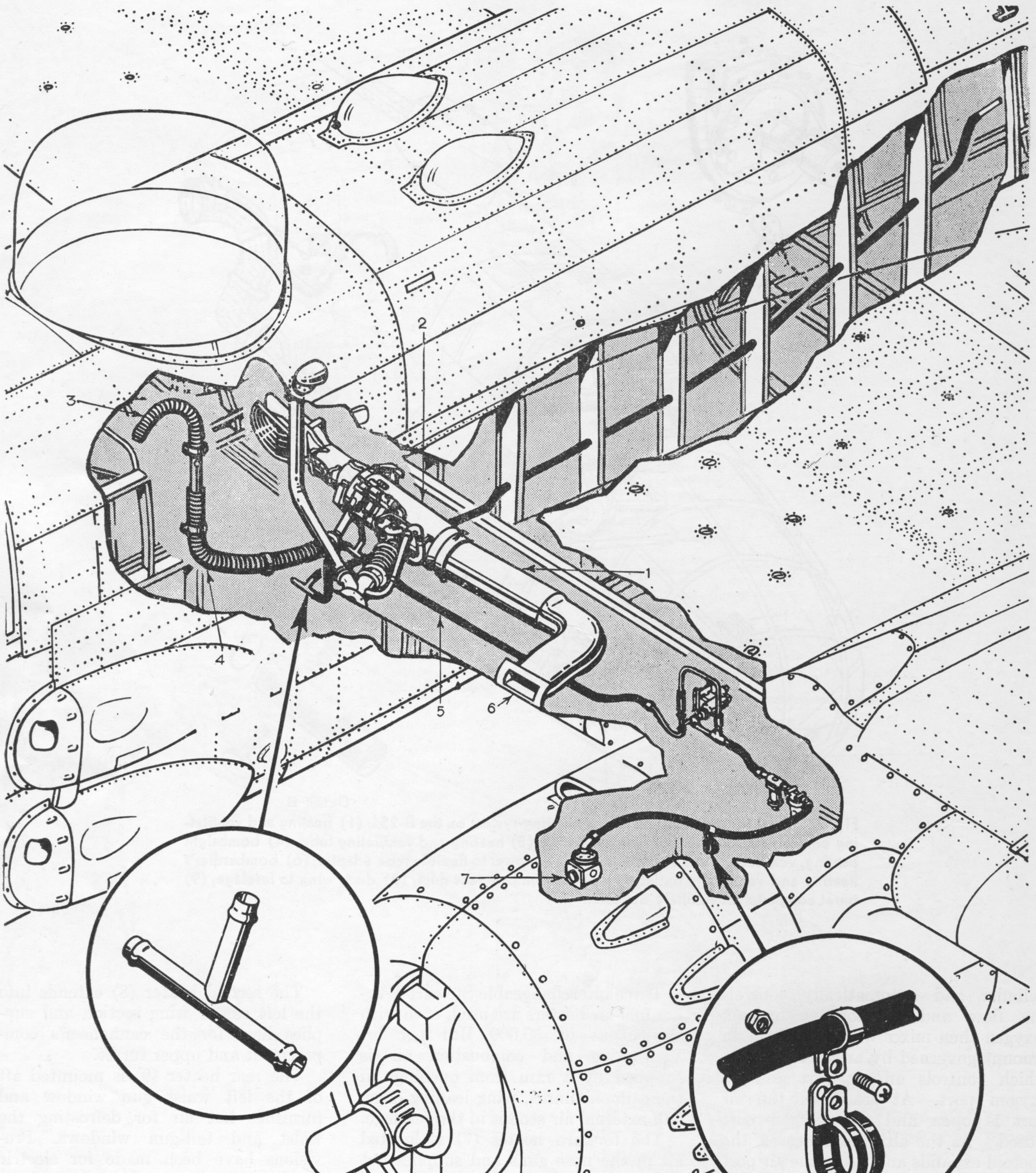


Fig. 8. Center section heating and ventilating system: (1) heater inlet duct; (2) heater assembly; (3) pilot's auxiliary defroster; (4) heating and ventilating air duct; (5) fuel hose line; (6) leading-edge air-intake scoop; (7) heater fuel pump.

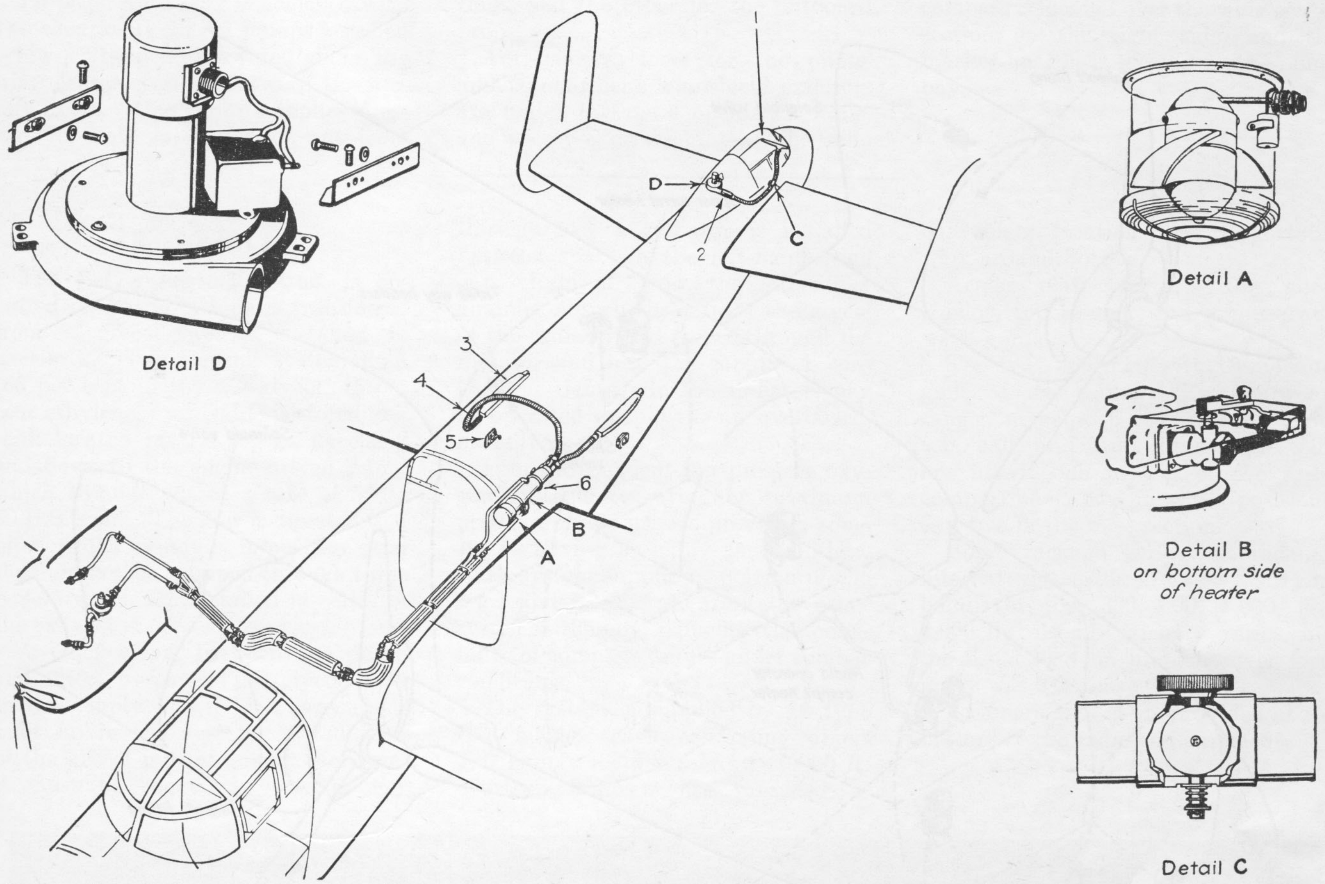


Fig. 9. Rear fuselage heating and ventilating system: (1) defroster for tail-gun window; (2) Avia defrosting heater for tail turret; (3) waist-gun window defroster manifold; (4) defroster tube; (5) system control; (6) heating and ventilating system, radio compartment.

Consolidated Vultee B-24

The Liberators carry a slightly greater load over a comparable distance than the B-17's, averaging about 3 tons to the latter's 2½ in practical operations.

Defensive armament consists of ten .50's in pairs in four power-operated turrets and from waist positions. Turrets are in the nose, top, belly, and tail. Armor plate protects the areas around all crew members and vital equipment.

Radio, interphone, and directional radio equipment aboard the B-24 derive power from the 24-volt d-c supply of the main power system. The interphone consists of an amplifier, dynamotor, jack box, and one throat microphone and microphone-amplifying equipment for each crew station. Each throat "mike" is equipped with switch cord or a push-to-talk switch.

Command radio, consisting of two transmitters and three receivers, is mounted above the wing center section just aft of the life rafts. A modulator unit, dynamotor modulator unit, and dynamotor are mounted aft of the compass receiver, on the rack for the radar equipment. The liaison radio includes one transmitter located on the flight deck, under the radio operator's table, and a receiver on the table. The radio compass is located over the wing center section on the right side, and the marker beacon is located in the bomb bay.

The capacity of the oxygen system, originally provided by five fixed-position bottles in the upper aft section of the outboard engine mounts, has been increased to 26 bottles of 350-psi type, located at strategic points. The pressure scale, translated in terms of altitude, is controlled by the user and maintained at a setting 5,000 ft higher than the indicated altitude.

The leading edges of the airfoils were originally designed for boot-type deicers, but all final models feature Convair's exhaust-heat anti-icing system. This made it necessary to provide ducts and double skins for conducting heated air to the L.E. surfaces. Edge strips, screwed to a ledge at the spar flange, make it possible to attach the L.E. by means of self-locking nuts in gang channels.

Air heated by exhaust gases is piped through the L.E. and the other parts of the plane—pilot's, radio operator's, tail turret's, and bombardier's compartments, and the upper turret position (1). Other crew positions rely on electrically heated clothing for protection.

The system consists of heat exchangers in the exhaust stack just ahead of the turbosupercharger, four in all, through which outside air is passed before flowing through ducts to the wing, empennage, and fuselage compartments. Ducting is aluminum sheet tubing covered with sheet asbestos, and averages 5 in. in diameter.

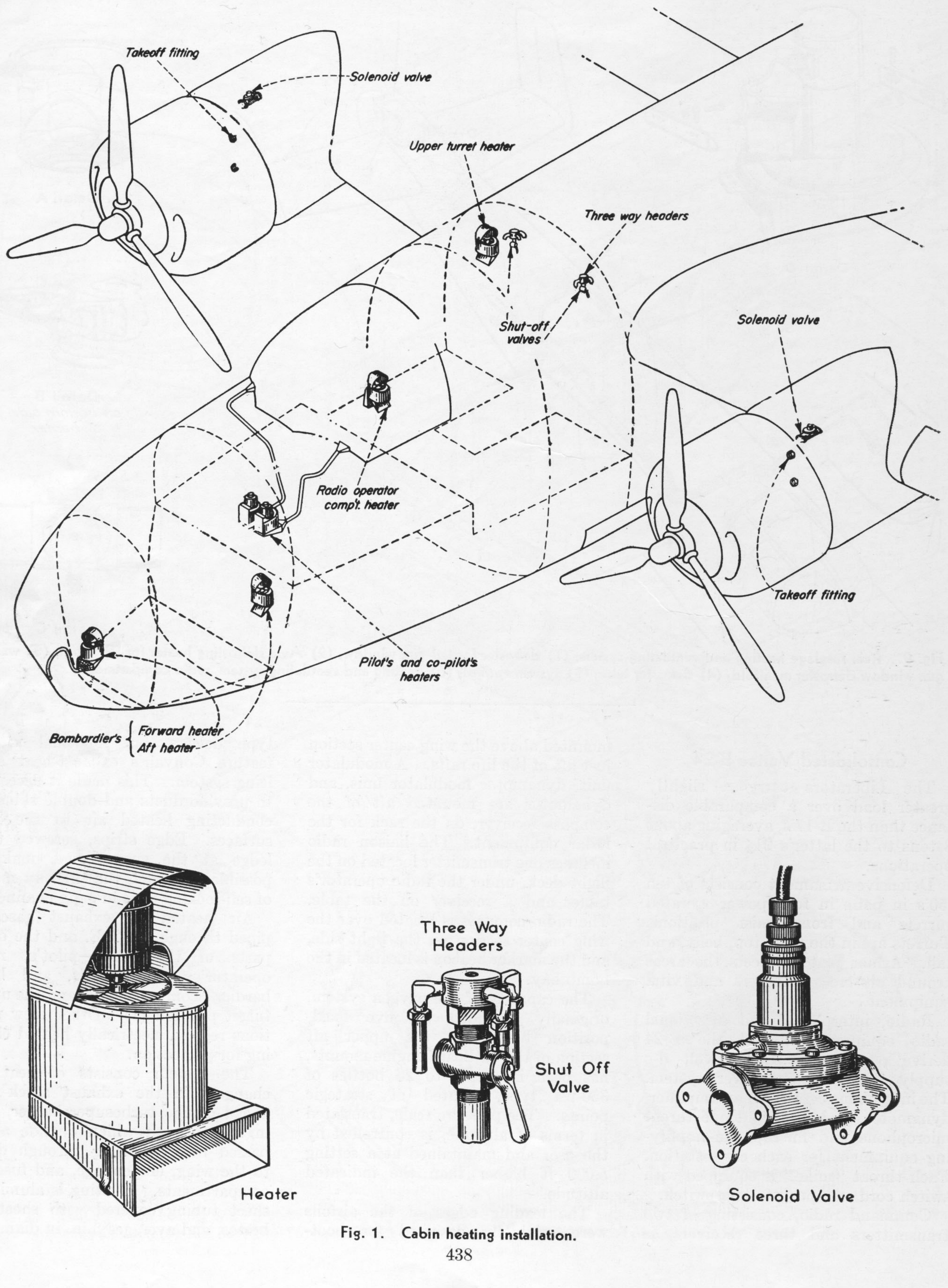


Fig. 1. Cabin heating installation.

Propeller anti-icing is achieved with two electrically driven pumps installed below a 21-gal tank located above the wing center section, between the life-raft doors. One pump supplies pressure for both inboard prop anti-icing rings, and the other for the outboard props.

Anti-icing systems for the pilots' and bombardier's windshield exteriors are under the radio operator's table, and a receiver on the table. The radio compass is located over the wing center section on the right side, and the marker beacon is located in the bomb bay.

Boeing B-17

The B-17's heating system is operated on hot air which is transferred from a glycol system installed in nacelle 2. The heating system fluid (55 per cent diethylene glycol, 45 per cent ethylene, by weight) is stored in a tank located in the top of nacelle 2 and flows to the engine-driven pump which circulates it at a rate of 55 to 60 U.S. gph. The flow is directed to a filter which removes impurities, and the fluid is then pumped through three boilers which are installed in series in the exhaust stack.

A relief valve, between the pump and filter, by-passes the glycol back to the supply line if high pressure is built up in the system. Circulation of the glycol is continuous; therefore, it must be constantly cooled. For this purpose a radiator is installed between spars in the left-hand wing gap. Ram air from the intercooler air inlet absorbs heat from the glycol at the radiator and passes through the radiator and into the cabin. A controllable damper in the radiator may be operated to spill the air overboard, if desired.

Four independent low-pressure oxygen systems operating at maximum pressure of 425 psi are provided, some B-17's having as many as 16 outlets. Each system supplies a portion of the crew and is separate from the other systems, thereby reducing the possibility of complete failure under combat conditions.

The system is supplied by 18 type G-1 bottles, each containing about 4-hr supply for one man at 30,000 ft. Thirteen brackets are provided in convenient locations for 10 portable walk-around bottles.

Armor plate protects the pilot, copilot, top gunner, tail gunner, and waist gunners.

The B-17 is armed with 13 machine guns of .50 caliber. Eight are arranged in pairs in four turrets—chin, top, ball, and tail. Five single .50's are fitted: one in top of the radio compartment, two in waist positions, and two in the nose section.

Bomb rackage varies but includes internal and external racks, carrying bombs of 100, 300, 500, 1,000, and 2,000 lb. Bomb capacity varies, but the usual load on missions over Germany was 2½ tons.

A camera well (1) is provided at the bottom of the radio compartment.

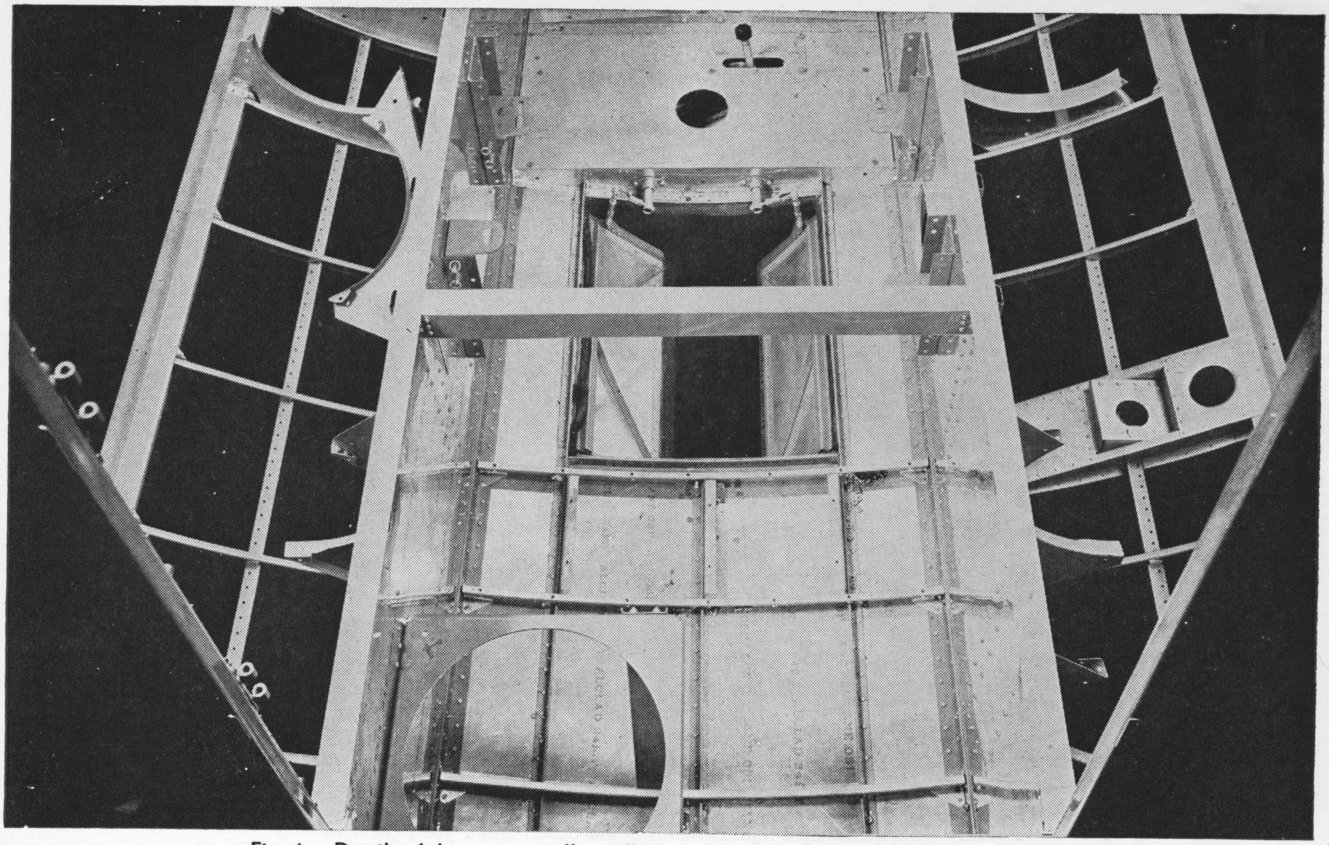


Fig. 1. Details of the camera well installation at the bottom of the radio compartment.

Douglas A-20

Since the A-20 was first designed, armor and armament have changed considerably. But despite the increasing weight and amount of both, no major basic alteration in the plane has been required.

The switch from .30- to .50-caliber machine guns and to 20-mm cannon, on some models, has required variations in the structures of the nose sections, and a minor change in the fuselage just aft of the bulkhead where the nose attaches, for a distance of approximately 30 in. aft, because of the greater weight of the nose. However, no changes were required in the main fuselage or wing structures.

An attack nose tip with four 20-mm cannon is removable (1). The tip is loosened through a circular access door on the side near the lower cannon. A shell box for ammunition supplying

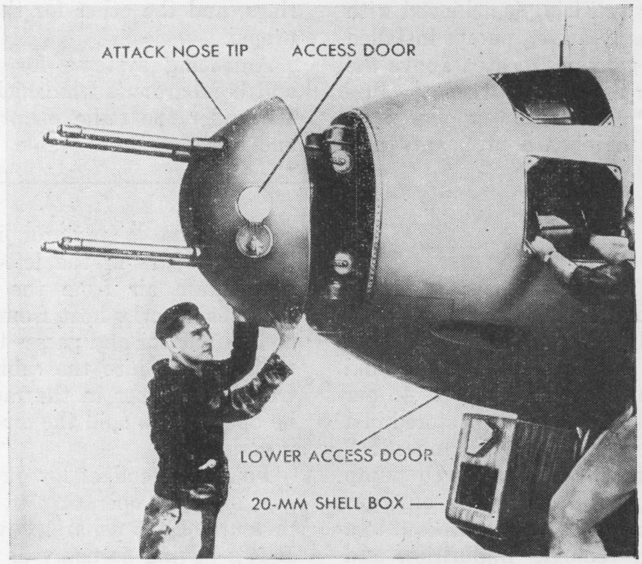


Fig. 1. Removing the attack nose tip. This part is loosened through a circular access door. The shell box (bottom) for cannon ammunition is inserted through the lower door.

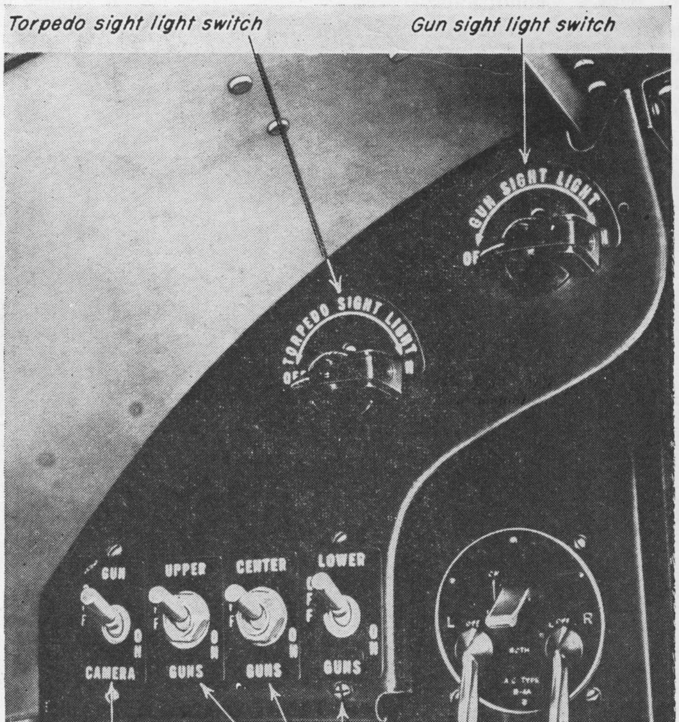


Fig. 2. Gun and gun-camera selector switches in the row at the lower left. A torpedo-sight light switch is at the center and a gun-sight light switch at the top right.

the cannon is inserted through a lower door aft of the nose-tip attachment.

In the center of the nose tip between the cannon is a gun-camera opening (3). Two .50-caliber guns are carried in the lower sides aft of the nose tip. Gun and gun camera selector switches are on the control panel (2) together with a torpedo-sight light switch and gun-sight light switch.

The pilot is protected by heavy folding-back armor plate (4), and excellent vision is provided from the cockpit which projects beyond the engine nacelles.

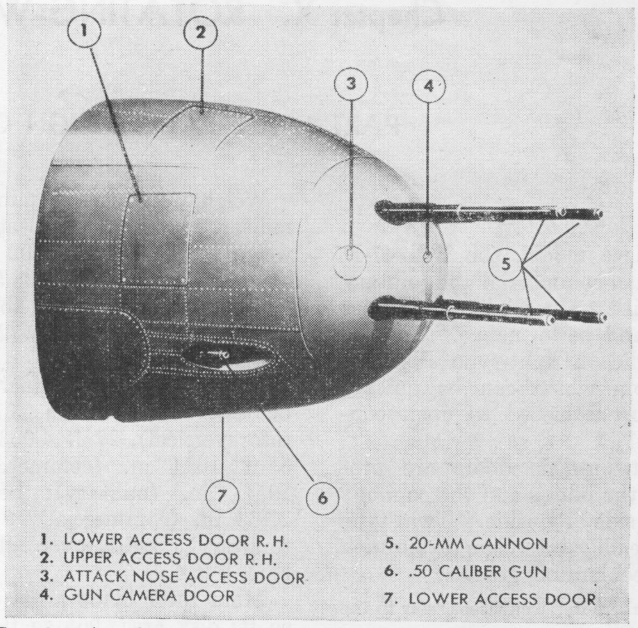


Fig. 3. Attack nose with 20-mm cannon. In the center is the camera opening. The lower sides carry .50-caliber guns. The circular door on the nose is for access to guns. The other doors are square openings at top, sides, and bottom.

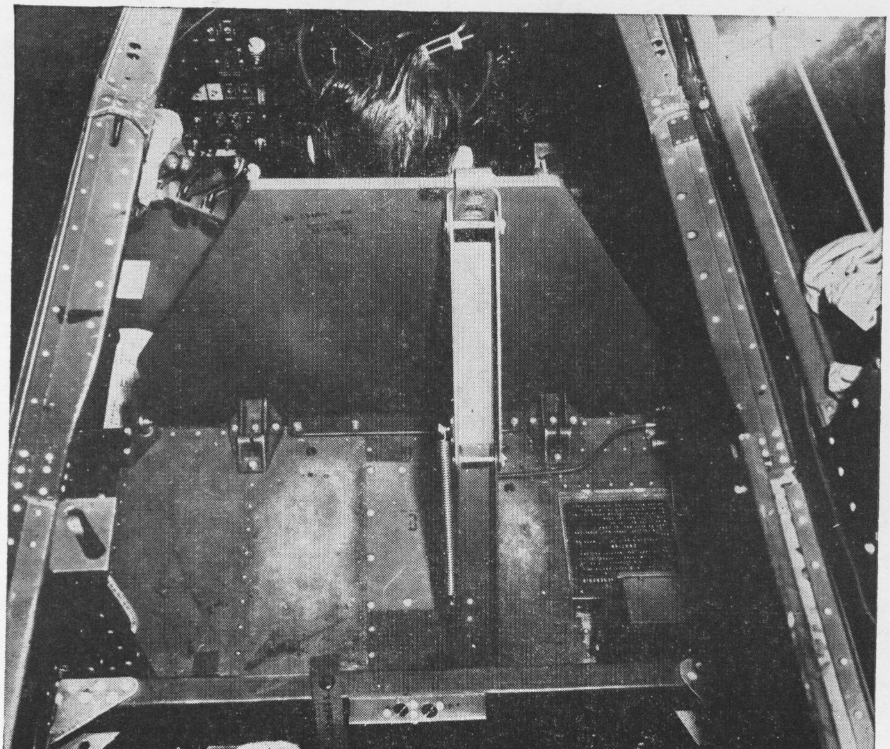


Fig. 4. Heavy folding-back armor for the pilot. Nothing short of a 40-mm shell can penetrate this.

Chapter X. ROTATING-WING AIRCRAFT

PART 1. GENERAL DESIGN CHARACTERISTICS

Bell 47-D

A two-place model, the Bell 47-D is produced in commercial and military versions with only slight differences in weight and performance. The design embodies a split-type Plexiglas bubble cabin which can be quickly converted from closed to open configuration (1).*

Two jettison-type doors are provided, and the pilot's and the copilot's seats are side by side. Twin-type floats are readily interchangeable with regular wheel landing gear.

* The numbers in parentheses refer to the illustrations.

Weights of the commercial and military models are, respectively: gross weights, 2,086 and 2,102 lb; weight empty, 1,482.5 and 1,508.5 lb; useful load, 603.5 and 593.45 lb; approved maximum gross weight, 2,200 (commercial model).

Over-all length (2) (including rotor blades), 41 ft 2.565 in.; fuselage (tail rotor vertical), 27 ft 4.003 in.; tread, 5 ft 10¼ in. (commercial), 5 ft. 10$\frac{5}{16}$ in. (military); height, 9 ft 2.163 in. (commercial), 9 ft 1¼ in. (military); width over all (stabilizer bar), 8 ft 4 in.

Main rotor blade area (each) 17.62 sq ft; disk area, 965 sq ft; preconing angle, 2.5 deg; disk loading (normal gross weight), 2.3 lb per sq ft; solidity ratio (based on .75 span), .032; power loading (normal gross weight), 12 lb per hp.

Tail rotor blade area totals 2.40 sq ft; disk area, 25.31 sq ft; solidity, .083; sweepback leading edge, 0 deg.

Maximum cruising speed at sea level (commercial), 92 mph; operating speed at sea level, 75 per cent of power, 85 mph; maximum rate of climb at sea level, 900 fpm; time to climb to 5,000 ft, 7 min; absolute ceiling, 12,500 ft; service ceiling, 11,500 ft; hovering ceiling (in ground effect), 5,400 ft; range (sea level, 75 per cent

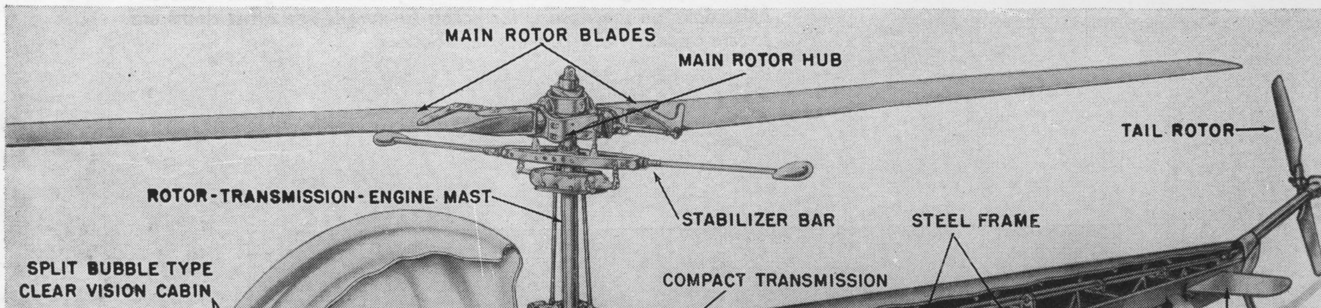


Fig. 1. Cutaway drawing of the Bell 47-D commercial model. The military version includes additional equipment such as two-way radio, heater, as well as an adjustable stabilizer. The fuselage is of steel frame construction.

power), 212 miles; endurance (sea level, 75 per cent power), 2.5 hr; maximum endurance (60 per cent power), 3 hr.

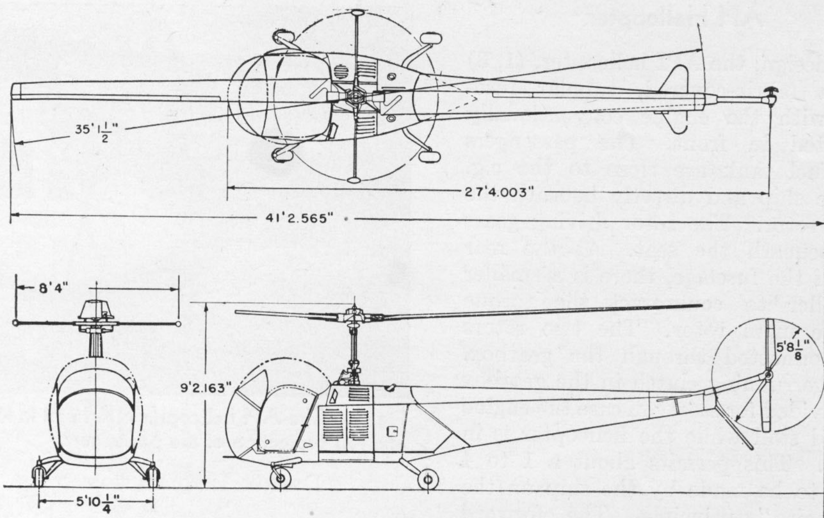


Fig. 2. Three-view drawing with principal dimensions of the commercial model 47-D.

Piasecki HRP-1

The largest helicopter now in production is the Piasecki HRP-1 which has performed a number of important jobs for the Navy, Coast Guard, and Marine Corps. This machine is a twin-rotor type with rotors at each end. It is 46 ft in length and carries two pilots and eight passengers, or their equivalent weight in cargo (1). The power plant is one 600-hp Pratt & Whitney radial air-cooled engine which is located abaft the main landing gear. The rotors are both 41 ft in diameter.

The HRP-1 has performed important rescue missions, has delivered heavy cargo in out-of-the-way places, and has operated from carrier decks.

An even larger machine is now under development by the Piasecki Company for the AAF. This machine, the XH-16, is approximately as large as a Douglas DC-4 transport and will carry a large detachable capsule beneath it. It will have a longer range than any other helicopter so far built.

Fig. 1. The Piasecki HRP-1 transport helicopter carrying a jeep during one of its experimental missions.

API Helicopter

In design, the API helicopter, (1, 3) has a fabric-covered, tubular fuselage with the engine conventionally mounted in front. The passengers and fuel tank are close to the c.g. of the ship and directly beneath the main rotor. The rotor driving gears are beneath the seat. At the rear end of the fuselage, there is a smaller propeller to counteract the torque of the main rotor. The two rotors are connected through the gearbox. An overrunning clutch in the gearbox is provided for safety in case the engine should stall while the helicopter is in flight. This permits about a 1 to 4 glide to be made by the ship on the "autogiro" principle. The forward position of the engine, which is a six-cylinder 165-hp Franklin, the positive cooling of this power plant, and a multiple V-belt drive are among the unique structural features (2). The use of a belt drive makes for easy engine service and provides both a flexible and shock-absorbing connection between the engine and the rotor. This is claimed greatly to reduce the vibration compared with that experienced when the engine is directly and positively connected to the rotors. The main rotor has three blades; the tail rotor, two. The battery is located behind the seat close to the c.g.

Fig. 1. The API helicopter NX-1272 in landing. This gives a good idea of the clean lines and full protection of the passengers.

Design Information

Passenger capacity	2
Cruising range	250–300 miles
Fuel capacity	20 gal
Speed, max	85–95 mph
Speed, cruising	80 mph
Gross weight	1,650 lb
Useful load	520 lb
Length of fuselage, overall	25 ft 8 in.
Height, overall	8 ft 5 in.
Width, overall	7 ft 11 in.
Fuselage, width, overall	3 ft 9 in.
Clearance, bottom fuselage to ground	1 ft $3\frac{1}{2}$ in
Main rotor blades	3
Main rotor diameter	30 ft
Tail rotor diameter	5 ft 8 in.
Engine	Franklin
Number of cylinders	6
Max. hp	165
Hovering hp	120
Cruising hp	90
Rpm ratio:	
Engine to main rotor	12
Tail engine rotor	1.92
Blade area, main rotor	46.2 sq ft
Individual blade area	15.4 sq ft
Main rotor disk area	706.8 sq ft
Gross weight (including pilot and passenger)	1,650 lb
Main blade, total loading	35.7 lb/sq ft
Main rotor, total disk loading	2.33 lb/sq ft
Take-off (165 hp)	10 lb/hp
Cruising (90 hp)	18.3 lb/hp
Hovering (120 hp)	13.7 lb/hp
Take-off (165 hp)	10.0 hp/100 lb
Cruising (90 hp)	5.4 hp/100 lb
Hovering (120 hp)	7.2 hp/100 lb

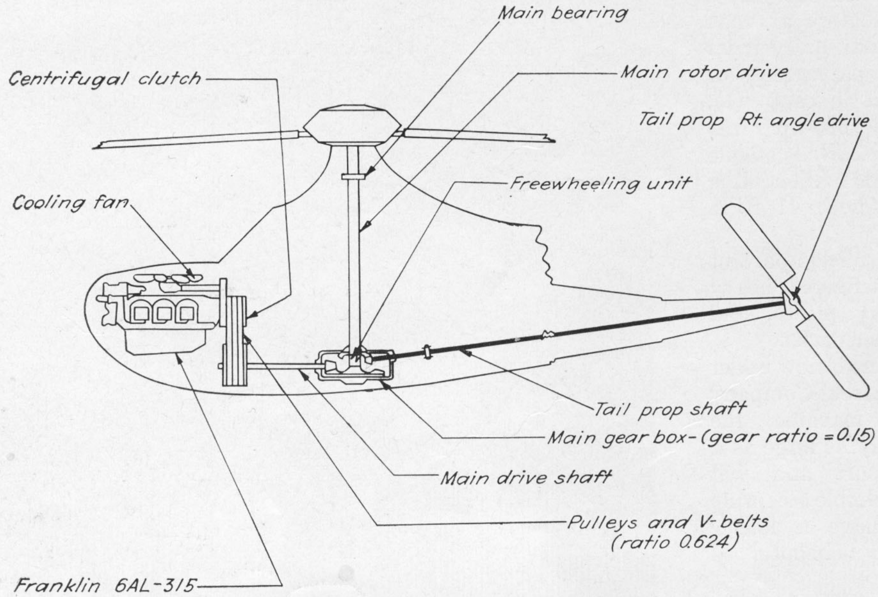


Fig. 2. The simplicity of the helicopter drive system is clearly shown in this view. The multiple-belt drive from engine to gearbox and belt-driven cooling fan are disclosed. Bevel gears in an aluminum housing at the tail drive the torque-resisting propeller.

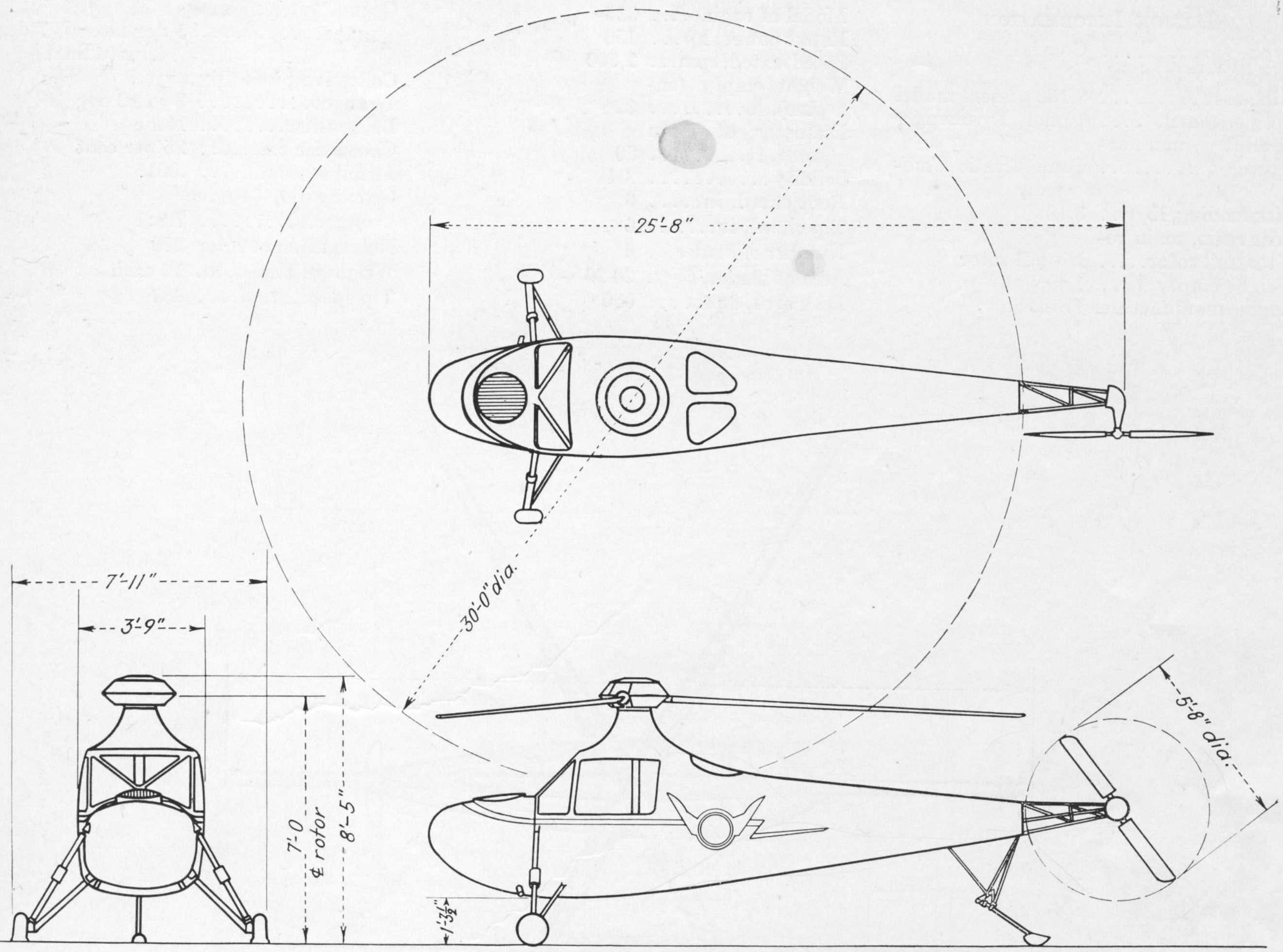


Fig. 3. General view of the API helicopter giving the principal dimensions.

Brantley

The Brantley is a coaxial-type helicopter manufactured by the Penn Elastic Company. It has six rotor blades having an over-all diameter of 29 ft (2). No tail rotor is provided, a vestigial tail of the conventional airplane type being installed in its place.

The fuselage resembles the conventional plane type also and is provided with forward main landing gear and rear tail wheel (1). The design gross weight of this two-place experimental helicopter is 2,100 lb; weight empty, 1,425 lb. With a disk area of 660 sq ft, disk loading is 3.18 lb per ft. Each of the rotor blades weighs 12 lb. The solidity is .04.

The helicopter is powered by a Franklin model 335 engine rated at 150 hp at 2,600 rpm. Weight of the engine dry is 324 lb.

Fig. 1. The fuselage of the Brantley is provided with conventional three-point landing gear and resembles conventional light plane construction with vestigial tail assembly.

Design Information

Type	Coaxial
Design gross weight, lb	2,100 present model
No. personnel	1 pilot, 1 passenger
Aircraft manufacturer	Penn Elastic Company
Disk loading, lb/ft.	3.18
Gear ratio, main rotor/tail rotor	No tail rotor
Weight empty, lb	1,425
Engine manufacturer	Franklin
Model of engine	335
Rated power, hp	150
Speed, rated, rpm	2,600
Weight empty (engine), lb	324
Diameter of main rotor, ft	29
Solidity	.04
Root chord, in	6
Tip chord, in	6
Number of blades	6
Area of blades, sq ft.	26.26
Disk area, sq ft	660
Cyclic pitch change range	5 deg lateral, 7 deg longitudinal
Collective pitch range	3 to 12 deg
Blade twist	None
Chordwise c.g.	25 per cent
Airfoil section	.0015
Gear ratio, engine/rotor	7.8:1
Normal rpm of rotor	320
Weight of blades, lb.	12 each
Tip speed	487

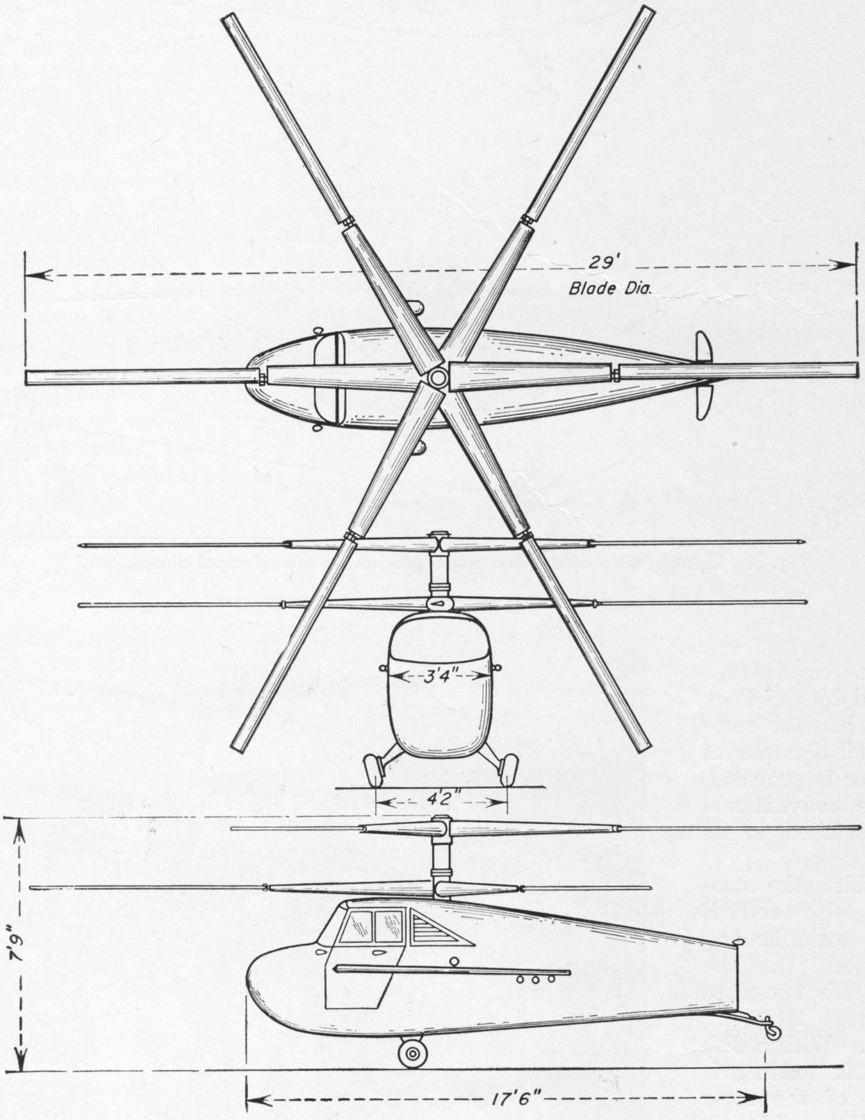


Fig. 2. Principal dimensions of the Brantley helicopter.

Sikorsky S-51 and S-52

The S-51 helicopter, like the R-4, has a tricycle landing gear and three-bladed rotor system as well as a tail rotor. Rotor blades from hub to tip are 24 ft in length. The over-all length of the S-51, including rotor blade diameters, is 57 ft ½ in.; tread is 12 ft wide and 10 ft 1 in. from nose wheel to main gear (1).

The S-52, a smaller craft of cleaner design, is also a three-blade rotor type with tricycle landing gear with an over-all length, including rotor diameter, of 38 ft 6¾ in. (2). It is a two-place side-by-side model and has a two-blade tail rotor instead of the three-blade type on the S-51.

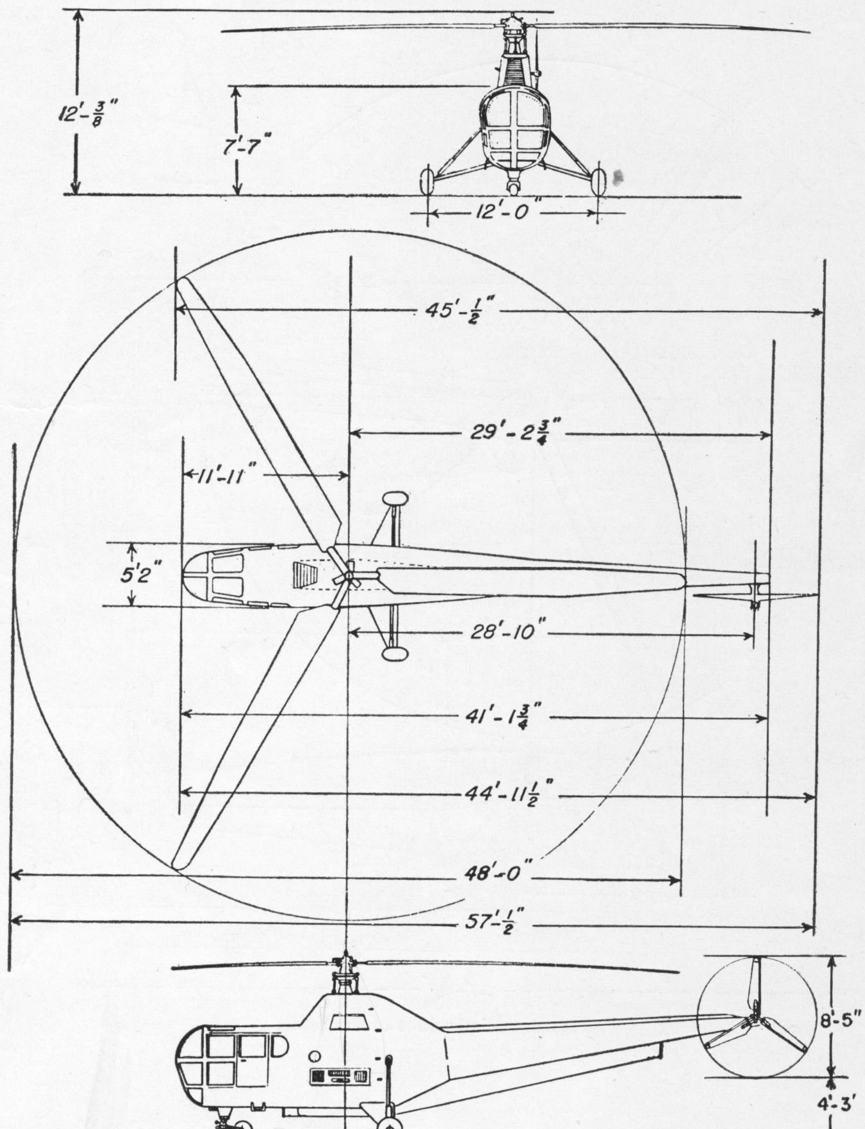


Fig. 1. Dimensions of the S-51 helicopter.

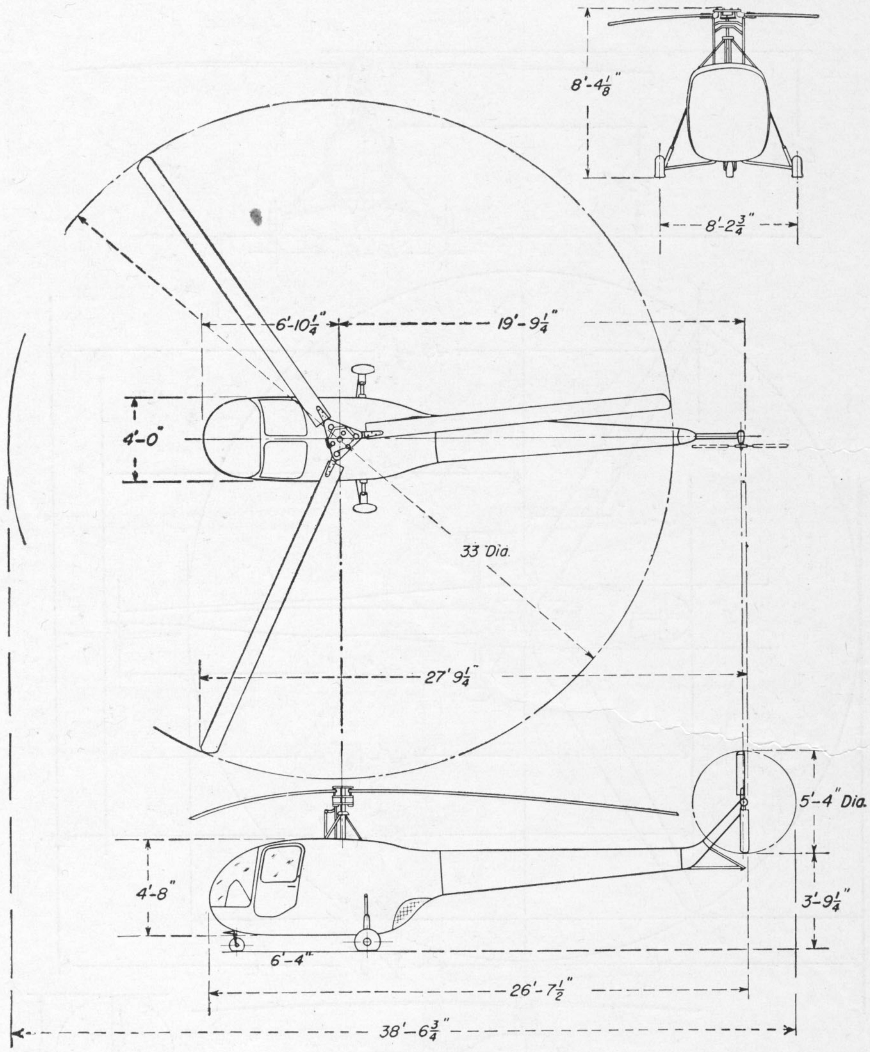


Fig. 2. Dimensions of the S-52.

Helicopters, Inc., Whirlaway, Model J

The engine in the Helicopters, Inc., Whirlaway is mounted to the rear of the rotor shaft and transmission (1).

The roots of the rotor blades are attached to metal cuffs (2). The side plates of the hub are of aluminum alloy, and the hub hinge is offset. The drive shaft is enclosed within the upper rotor support. Between the rotors are the control linkage and swash plates. Three torsional mounts are provided for the rotor system.

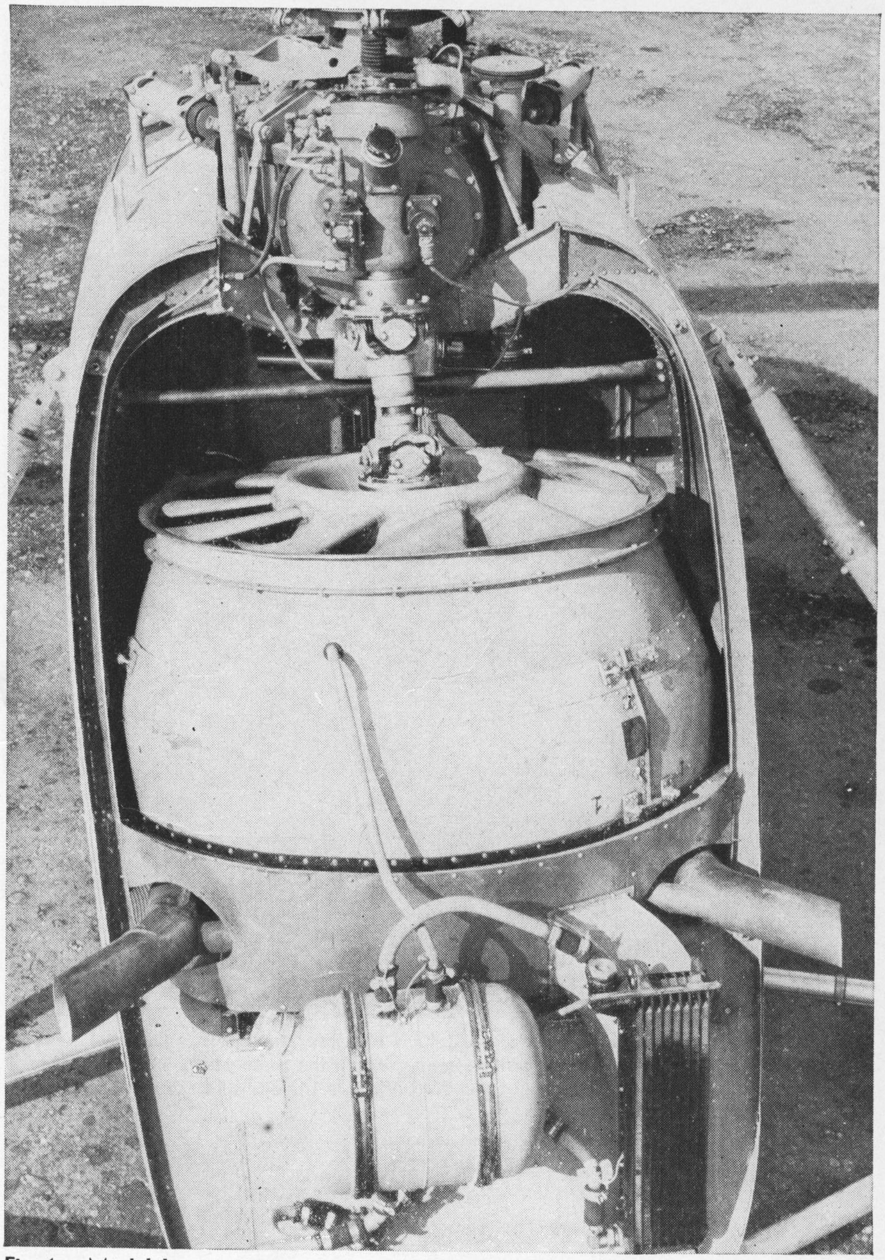


Fig. 1. Model J engine compartment showing (from the bottom up): engine oil tank and oil cooler between exhausts; engine cooling shroud; fan (mounted to flange on clutch); drive shaft with universal ends; overrunning clutch; and transmission.

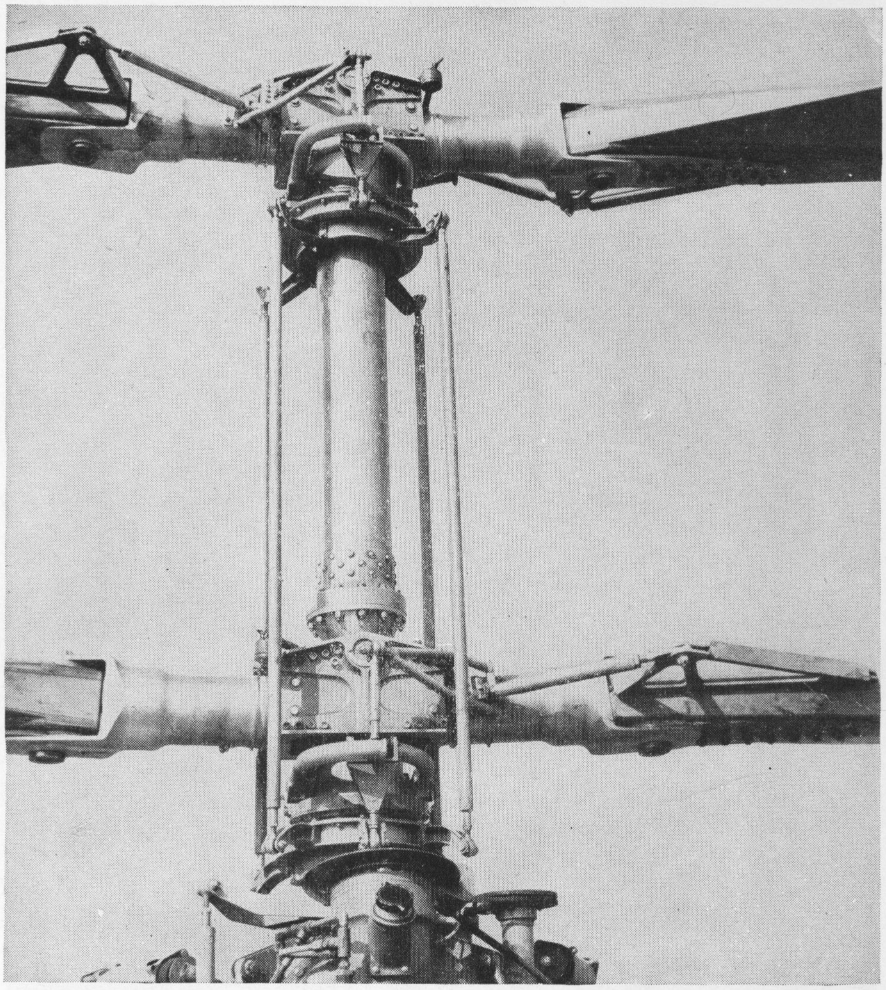


Fig. 2. Close-up of the rotor system on model J Whirlaway, showing attachment of the roots of the rotor blades to cuffs. At the bottom center, below the swash plate, are the rotor brake disk and oil filler cap for transmission. At the bottom left is one of three torsional mounts for the rotor system.

Sikorsky R-4

The fuselage of the R-4 is of tubular construction and is provided with tricycle landing gear, the main gear forward. Seating a pilot and passenger side by side, the engine is installed just aft of the cockpit and forward of the three-bladed rotor system (1). A tail rotor is provided. The fuel tank is installed amidships, aft of the rotor system.

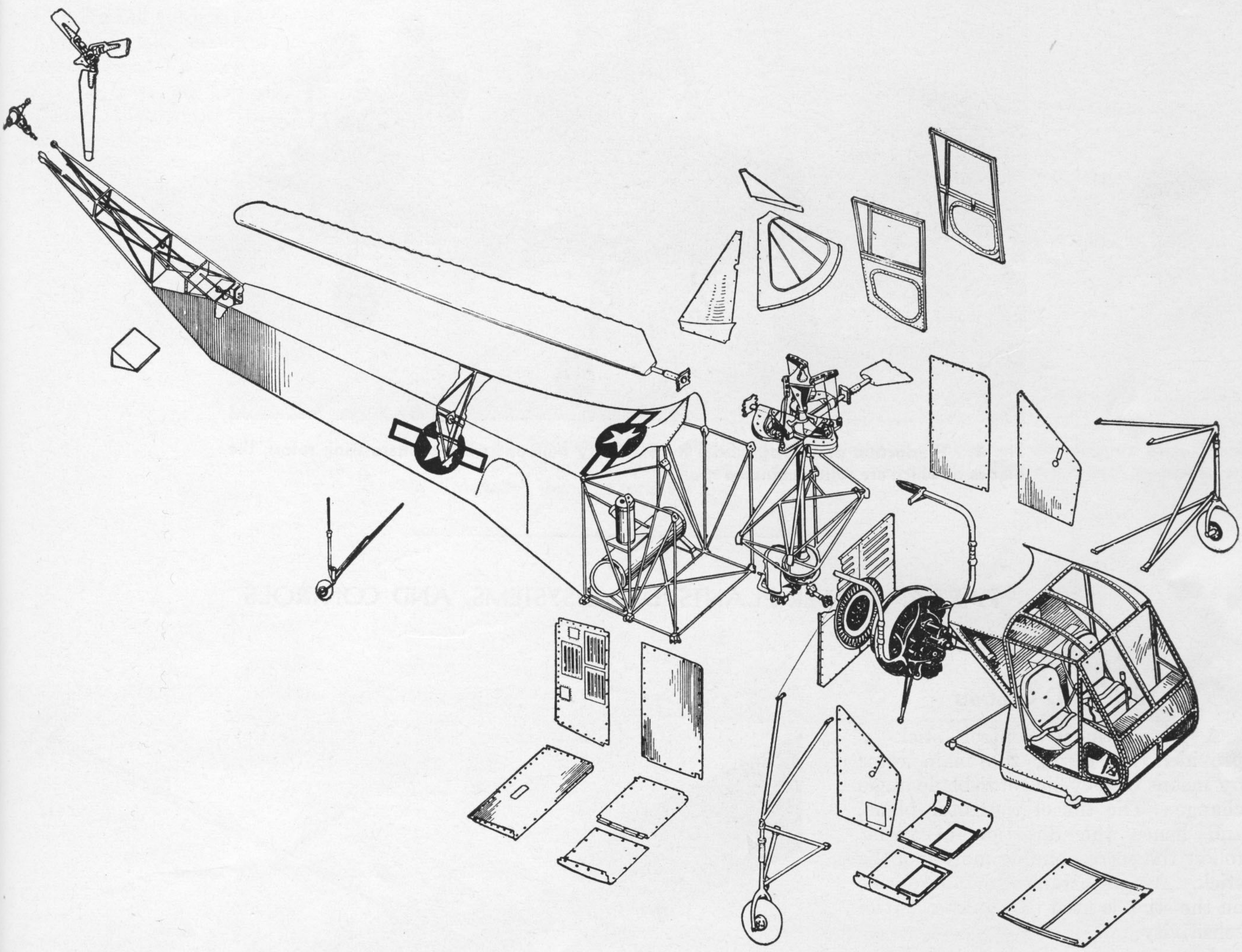


Fig. 1. Exploded view showing the major components of the Sikorsky R-4 helicopter which was used by both the AAF and the Coast Guard during the Second World War.

Kaman K-190 Utility

Designed specifically for utility purposes in agriculture and industry, the K-190 is engineered to provide easier flying characteristics, higher performance, greater serviceability, and lower initial and operating costs for helicopter operators in aerial dusting and spraying, oil-industry work, pipe-line patrol, etc.

Prime consideration was given to safety, dependability of operation, and ease of maintenance. Only those components directly contributing to these factors are incorporated in the machine. Fuselage covering, upholstering, and other units which increase weight, reduce pay load, increase maintenance costs, and are nonessential to utility operations, were eliminated (1).

Powered by the Lycoming 190-hp air-cooled engine, the Kaman K-190 is provided with contrarotating intermeshing rotors which eliminate the tail antitorque rotor necessary on single rotor helicopters, and reduce the pilot's required control coordination.

Weight empty, 1,700 lb; gross weight, 2,500 lb; useful load, 800 lb; seating capacity, pilot and two passengers; fuel capacity, 32 gal; range, 235 miles; operational ceiling 11,000 ft; cruising speed, 70 mph; top speed, 95 mph.

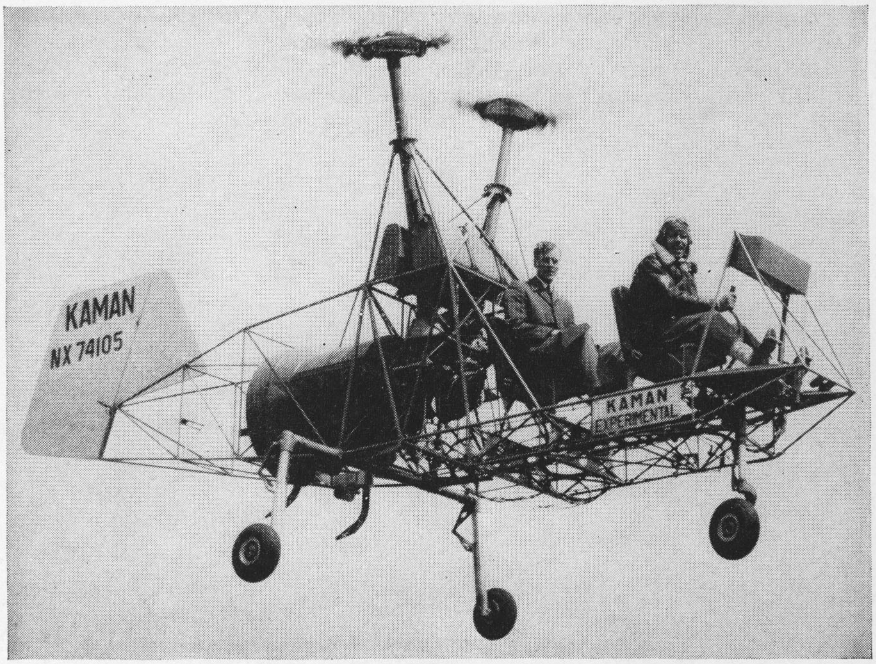


Fig. 1. Production prototype model K-190 utility helicopter has contrarotating rotors, the blades of which are solid laminated spruce.

PART 2. POWER PLANTS, DRIVE SYSTEMS, AND CONTROLS

Bell 47-D Controls

A conventional control stick is provided for tilting the main rotor by means of a cyclic rotor-blade angle change. The tilt of the rotor plane, and hence the direction of flight, follow the corresponding motion of the stick. An adjustable friction device on the stick is used to regulate control sensitivity.

A main rotor pitch-control lever, operation of which causes each rotor blade to increase or decrease its geometric angle a like amount, is located at the left of either seat. Upward motion of this lever produces greater lift, and the helicopter will ascend. Downward motion produces less lift and causes descent.

A pair of tail rotor pedals are connected to the pitch-changing mechanism of the tail rotor. Operation of these pedals permits proper torque compensation and also directional control.

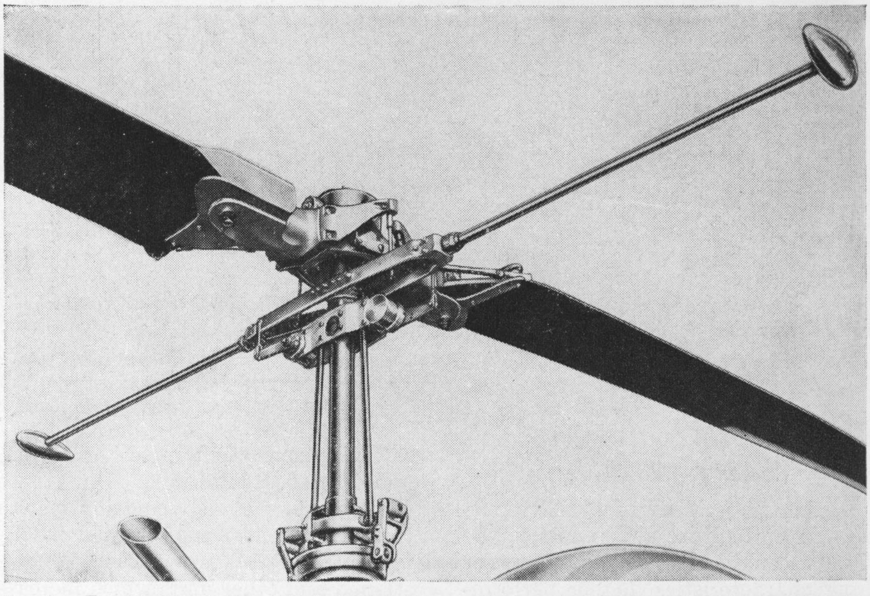


Fig. 1. The 47-D stabilizer bar is mounted on a "seesaw" pivot immediately beneath the main rotor. It rotates with the mast, at right angles to the rotor blades. Linked mechanically to the rotor, the stabilizer bar counteracts sudden changes of rotor blade angle.

The main rotor is a single two-blade type with stabilizer bar (1). This bar supplies an absolute-horizon base with respect to which the main rotor is controlled independently of the body. During maneuvers the freedom of the stabilizer bar is limited by hydraulic dampers. This arrangement provides excellent stability for the craft.

Helicopters, Inc., Whirlaway, Models J and K Rotors

The Helicopters, Inc. (formerly Bendix Helicopter, Inc.), models J and K rotary wing aircraft have two contrarotating rotors, mounted one above the other on the same shaft (1). No tail rotor is necessary.

The fuselage structure within the nonstructural fuselage shell is tubular (2). A cowl on top of the engine encloses the engine cooling fan. In the experimental model one seat, the pilot's, is provided. Landing gear is of the tricycle type.

Fig. 1. Model J helicopter with tail cone removed. The screen openings on each side of the engine compartment are exits for engine cooling air. The rotors are contrarotating, obviating the need for a tail rotor.

Fig. 2. One side of the three-section fuselage shell removed from the model K Whirlaway showing the tubular structure. The cowl on top of the engine encloses a cooling fan.

API Helicopter Controls

The main rotor of the API helicopter, a three-bladed disk 30 ft in diameter, is atop a 3½-in.-OD vertical driving tube, the lower end of which is attached to the big driven bevel gear (1). The tube and main rotor turn at one-twelfth engine speed. This constitutes the entire drive system of the helicopter. The main and tail rotors are fabric-covered. The main spar of each is a metal tube to which the wooden former ribs are attached. The main rotor tube is reduced in diameter in several steps between the root and the tip of the blade. This is done to reduce weight and keep the strength in proportion to the needs.

The main rotor blades are secured to the pitch-control hub by four taper-pin bolts that pass through the inner end of the tubular blade spar. The hub is mounted on two combination radial and thrust ball bearings at its inner end and on a Torrington needle bearing just inside the inner end of the blade spar. The pitch-control arm is welded to a split sleeve which clamps onto the outside of the blade hub. The tube, which forms the axis about which the blade turns in changing its pitch, has a forked inner end. This fork is mounted on a pin that lies in a horizontal plane (3).

At the tail of the helicopter there is a small two-blade variable-pitch torque-resisting propeller. This is driven by a tubular horizontal transverse shaft mounted on ball bearings and projecting out on the port side of the fuselage (2). The purpose of this propeller is to counteract the torque of the main rotor. In normal position the torque of the main rotor is exactly compensated and the heading of the ship is unchanged. To change the heading, the pitch is increased or decreased either to turn against the torque or allow the torque to override it. This steering control is obtained by steering pedals just as in a conventional airplane and is entirely independent of the flight attitude developed by changing the cyclic pitch of the main rotor.

The method of controlling the pitch is very simple. A rod passing through the hollow prop shaft is operated by a bell crank and cross bar. To the ends of the latter are attached the (rudder) cables. The outer end of the rod has a T bar that

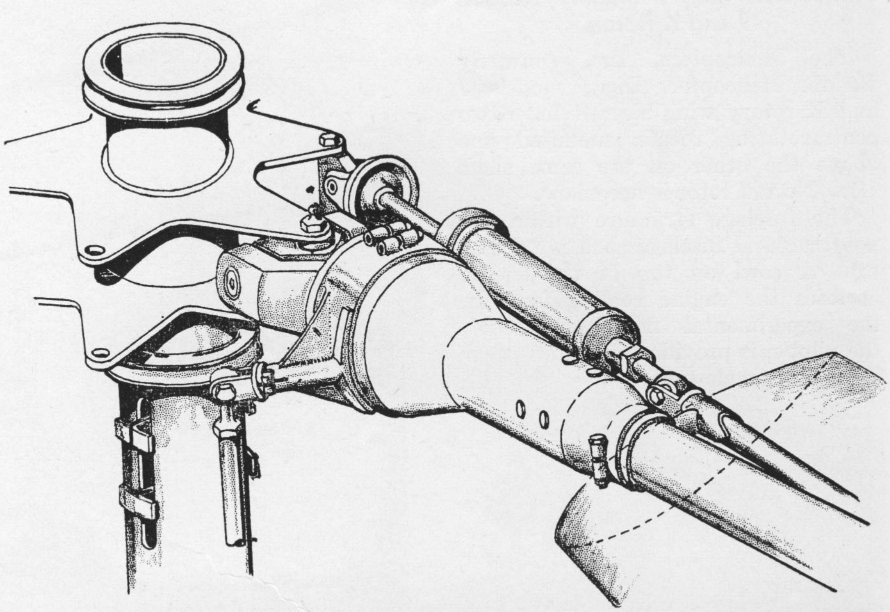


Fig. 1. Sketch showing the mounting of the main rotor blade on the central spider. The control of the blade pitch is obtained by the lever arm and rod at the left of the blade hub. At the right is the direct-acting hydraulic shock absorber which steadies the blade and limits its motion about the vertical axis of the universal joint where it is attached to the central spider.

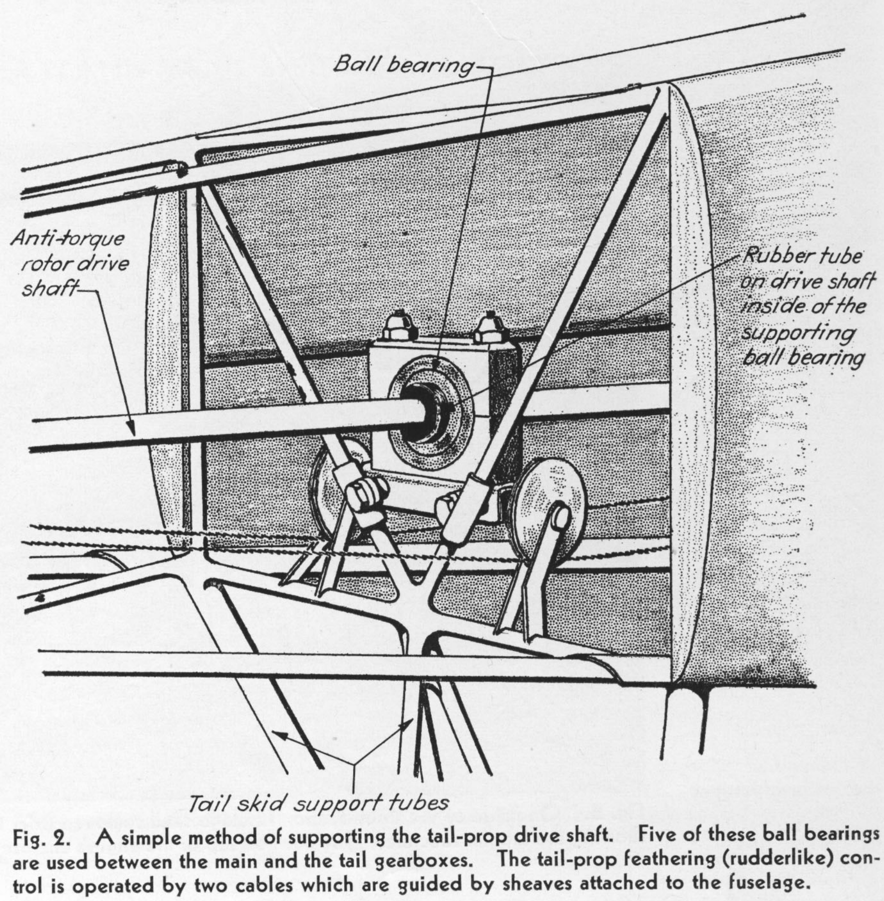


Fig. 2. A simple method of supporting the tail-prop drive shaft. Five of these ball bearings are used between the main and the tail gearboxes. The tail-prop feathering (rudderlike) control is operated by two cables which are guided by sheaves attached to the fuselage.

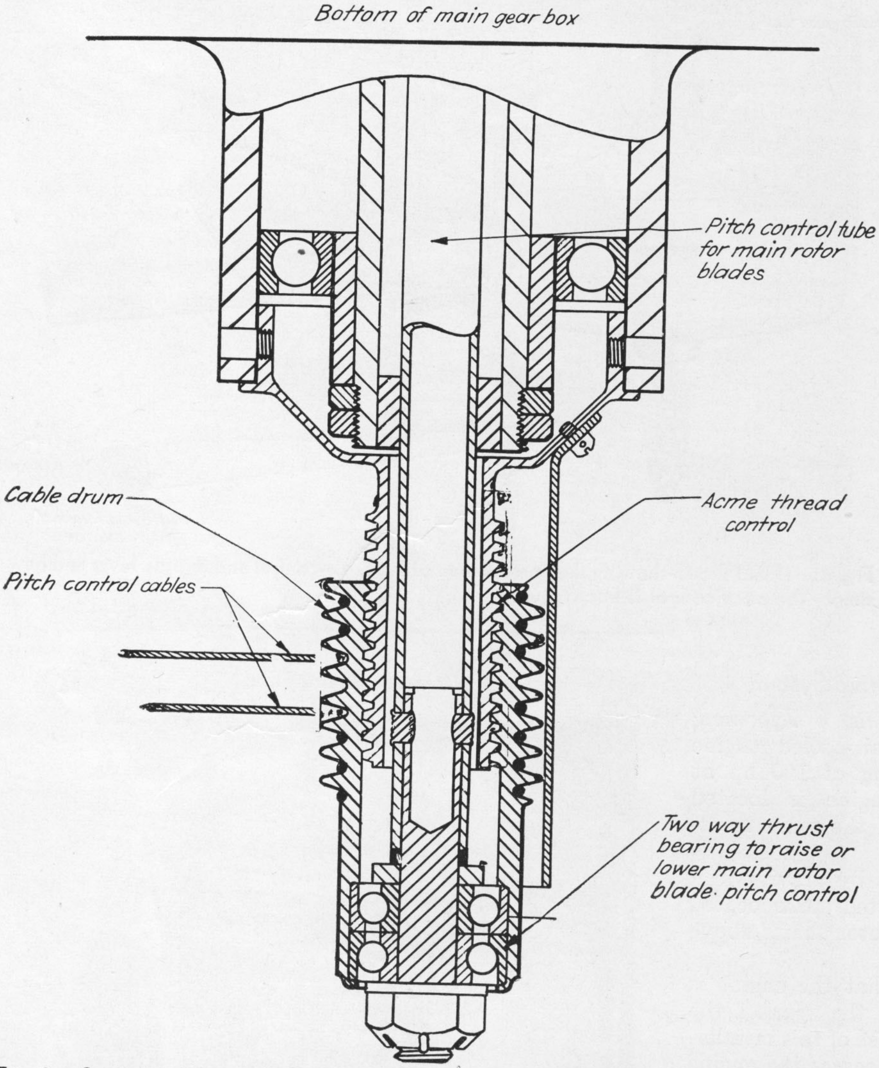


Fig. 3. Sectional drawing showing how the pitch-control drum is mounted on the bottom of the main gearbox and raises and lowers the vertical tube through the center of the main rotor drive tube.

is connected through adjustable ball-and-socket links to pitch-control arms on each variable-pitch blade. A light metal guide housing bolted to the prop hub causes the control shaft to rotate with the propeller. At the inner end of the control rod a ball-and-socket mounted ball thrust bearing is provided in the hub of the shifter yoke. Being inside the cast gear housing, it is completely protected from the elements.

Direction or heading is controlled by two pedals just as in a conventional ship, but actually it controls the pitch of the tail prop as previously explained.

A motorcycle-type throttle grip is incorporated in the handle of the main blade pitch-control lever that is operated by the pilot's right hand. Since the greater the pitch, the more the lift and the more the power required. Hence it is quite natural to turn or open the throttle as the lever is moved forward to increase the pitch. A pointer on the pitch-control lever sweeps over a quadrant graduated in pitch angles so the pilot at a glance can see the angle of attack (4).

The cyclic pitch control is governed by the position of the stick. To reduce weight to a minimum and provide positive direct action, the stick control is suspended from above instead of supported from the floor. A simple system of pulleys and cables swings a swash plate for lateral controls while fore-and-aft movement of the stick is followed by blade movements in that direction.

The blade pitch control is very simple. It is obtained through a rod which rotates with the vertical drive tube but moves up and down axially. Its control is by cables operating a screw and nut device projecting from the bottom of the gearbox.

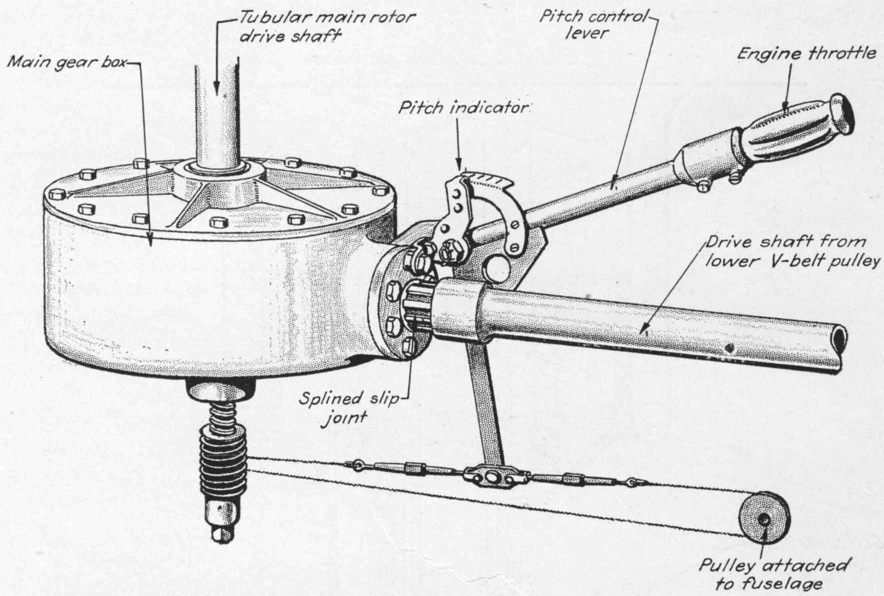


Fig. 4. Detail sketch showing the combination of the pitch-control and throttle lever and how simply the pitch control is hooked up.

Kaman K-190 Drive System

The power plant is a Lycoming O-435, six-cylinder air-cooled engine with maximum rating of 190 hp at 2,550 rpm. The engine is located below and to rear of the main transmission (1).

The fuel supply is by gravity feed from two interconnected tanks located fore and aft of the rotor shafts above the transmission.

It will be noted that the engine is mounted to face to the rear of the fuselage. The purpose of this installation is twofold. It locates the engine close to the helicopter center of gravity, and it provides maximum accessibility for engine replacement and maintenance.

A centrifugal clutch is mounted on the engine side of a fan disk. The clutch engages at 1,200 to 1,500 engine rpm and drives a simple two-spur gear transmission mounted on the engine nose. This engine nose transmission, which has a 1.1:1 gear ratio, transmits power to the drive shaft, which in turn drives the main transmission via a free-wheeling unit incorporated for purposes of autorotation. The drive shaft is universally mounted at both ends to allow for misalignment during operation. A single disk hydraulic rotor brake is located on the main transmission at the free-wheeling unit to provide quick stopping of the rotors after engine shutdown.

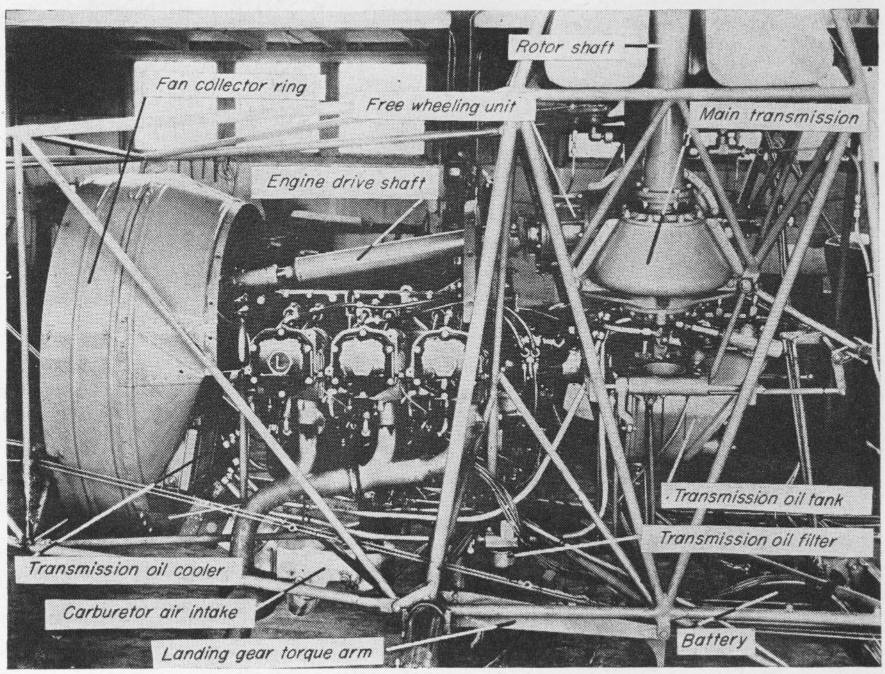


Fig. 1. Engine and transmission installation (full right side), showing the engine located aft and below the main transmission.

Gear ratio in the main transmission is 10.5:1, and this, together with the 1.1:1 ratio in the nose transmission, gives a ratio of 11.55:1 between the engine and the rotors.

The rotor shafts are two-piece, being flange-bolted just above the main transmission (2), thereby facilitating disassembly and installation of the shafts. The shafts are chrome-moly tubing with the mating flange welded at the bottom and a cross tube for the hub drive welded at the top.

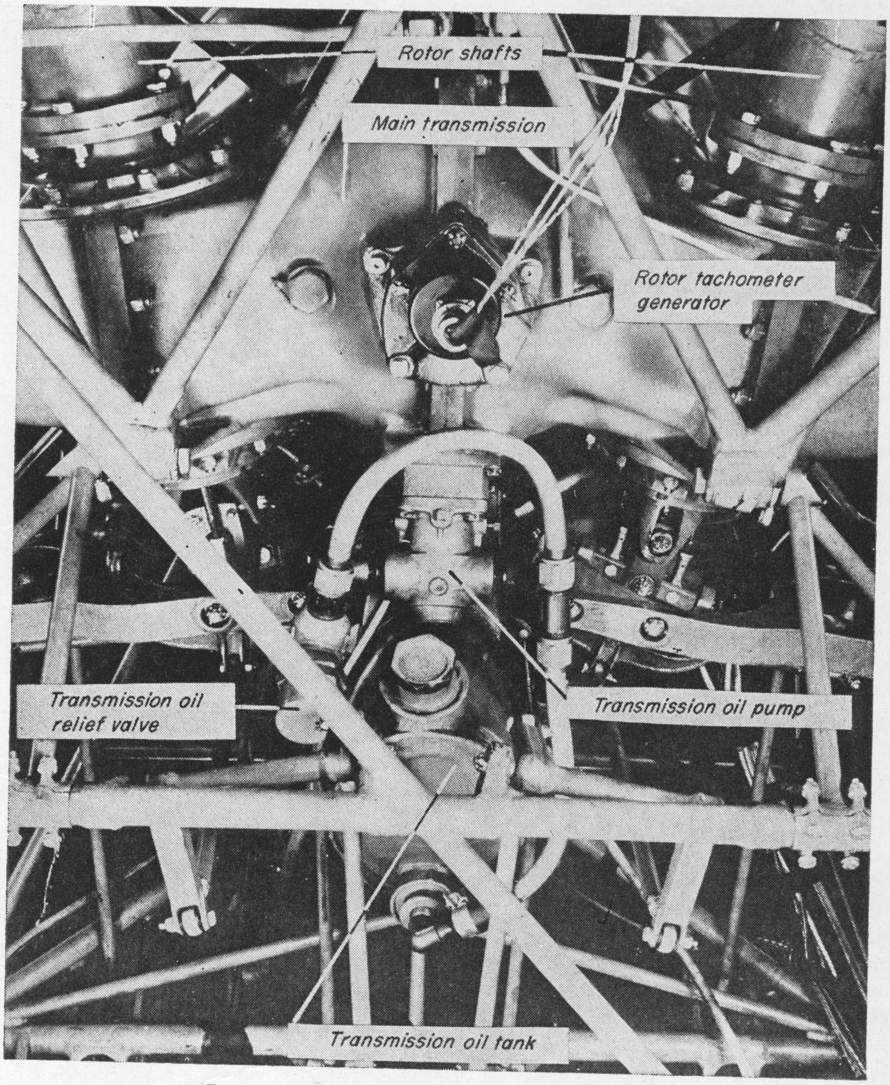


Fig. 2. **The rotor shafts of the K-190 helicopter.**

Doman R-6A Rotor

The Doman Helicopter model R-6A incorporates a hingeless type of rotor unit which is dynamically flexible but otherwise unarticulated. It is a four-blade rotor type with tail rotor (1).

Removable steel spars are used to attach the four blades to the hub, which includes a housing enclosing a swash plate, control cylinders, oil pump, and governor (2).

Fig. 1. **The Doman R-6A is a conventional four-blade rotor type with tail rotor.**

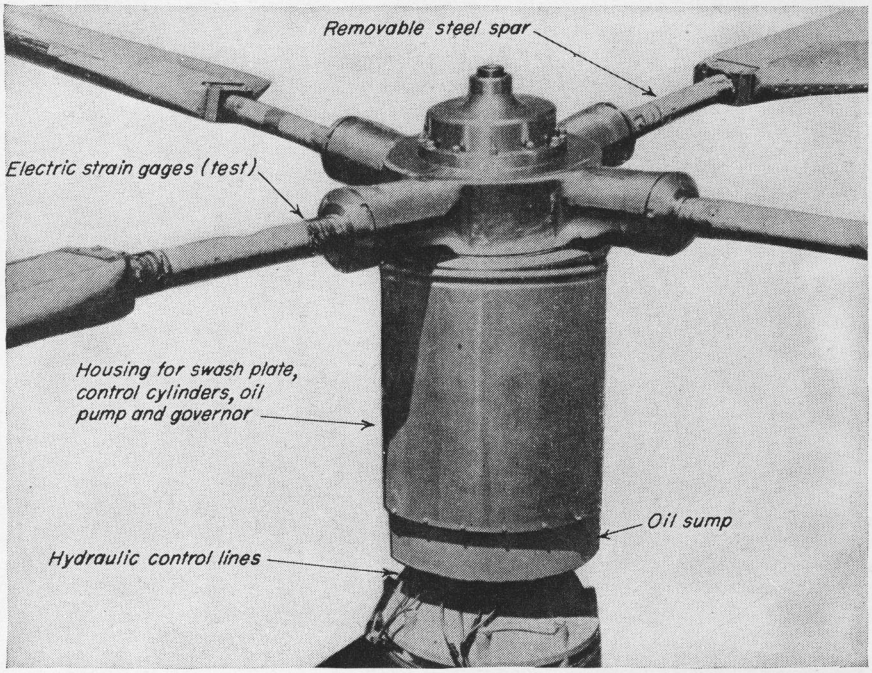


Fig. 2. A hingeless rotor unit is used in the R-6A which is dynamically flexible but otherwise unarticulated.

Kaman K-190 Rotors and Controls

The use of conventional rotors and rotor controls in the intermeshing system raises problems of weight, production costs, maintenance, and control force feed-back factors which, when compared with single-rotor machines, become double. It was necessary to achieve such simplification of the rotors and controls as would reduce by more than half the values of these factors.

Paramount consideration was given to a servo-flap type of rotor control (1) which would obviate the use of blade-pitch change and associated bearings and greatly simplify rotor hub and blade construction.

The pilot controls in the K-190 are conventional, there being a cyclic stick, a collective-pitch stick incorporating the throttle, and rudder pedals (2). By means of a torque tube (3) and push-pull rods (4), the sticks and pedals are connected to the collective-pitch forks and gimbal-ring assemblies located at the base of the rotor shafts (5).

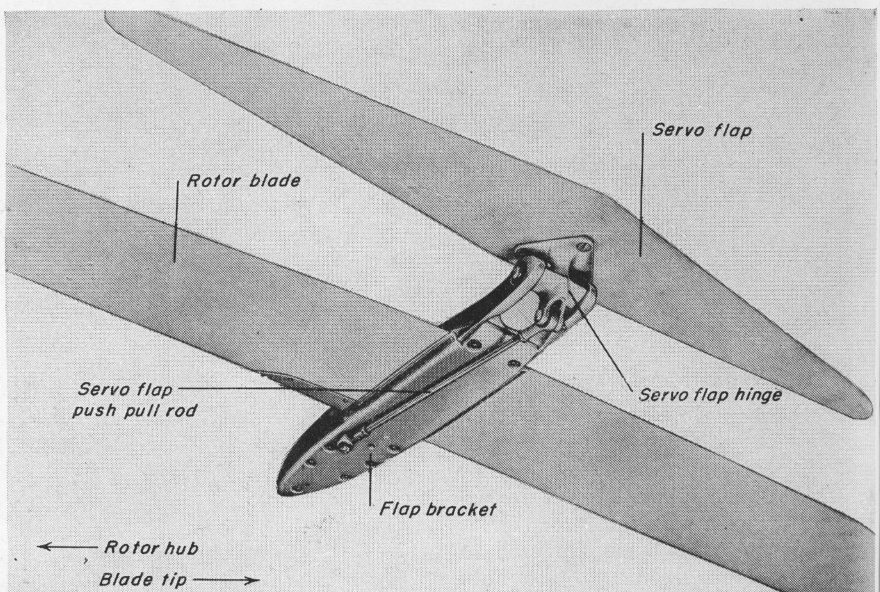


Fig. 1. The Kaman servo-flap installation eliminates the use of blade-pitch change and associated bearings and greatly simplifies rotor hub and blade construction.

Pilot control applied to these assemblies is transferred through push-pull rods inside the hollow rotor shafts, through bell cranks at the rotor hub to

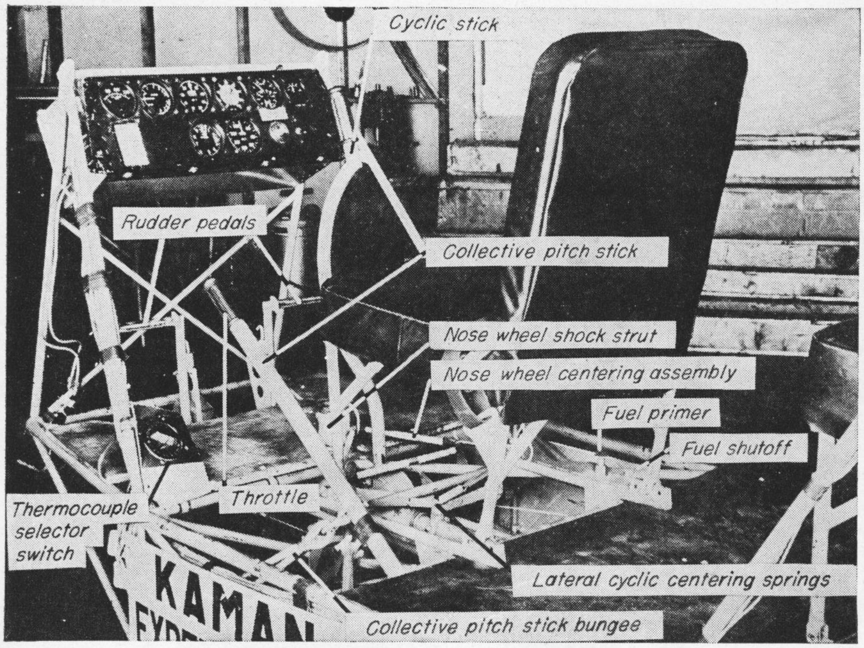


Fig. 2. K-190 cockpit control installations.

push-pull rods located in the blade leading edge (6), and finally through a bell crank in the servo-flap bracket to attach directly to the servo-flap hinge (1).

Cyclic control is obtained by tilting the gimbal-ring assembly thereby causing a rocking motion which is carried to the servo flap as the gimbal ring rotates with the rotor.

Movement of the collective-pitch stick raises and lowers the two gimbal-ring assemblies simultaneously by means of the hinged collective-pitch forks. This provides equal pitch increase or decrease to all servo flaps through the full 360-deg sweep of the rotor.

The rudder pedals raise and lower the two gimbal-ring assemblies alternately by means of the collective-pitch forks, which movement increases the collective pitch of one rotor while decreasing the collective pitch of the other. This provides a torque differential between the rotors which is utilized for directional control.

In addition, the rudder pedals are connected to a movable vertical tail surface which not only results in greater maneuverability in forward flight but also provides positive directional control in autorotation.

The rotor blades are of solid wood, being formed from a block of laminated spruce planks. When equilibrium is disturbed by the introduction of positive pitch on the servo flap, an aerodynamic moment is introduced which reduces the pitch of the rotor blade by twisting between the root and the ¾-radius station at which the servo flap is located.

Conversely, the introduction of a negative pitch on the servo flap increases the pitch of the rotor blade. To reduce the servo-flap movement required, there is a built-in positive blade angle. Natural resilience of the spruce rotor blade is utilized to accomplish this torsional deflection.

It is interesting to note that conventionally controlled rotor blades require high torsional stiffness to avoid torsional deflection. To attain torsional stiffness generally requires stiffness in bending, and this, depending on the natural frequencies involved, usually results in problems of vibration.

The Kaman rotor blade has low stiffness in both torsion and bending which results in the ship's being inherently smooth and free of vibration. Extensive fatigue tests on specimen blades are said to have proved the blades against torsion fatigue failures.

Since the principal working portions of a rotor blade are located at the outer third of the radius, it was initially

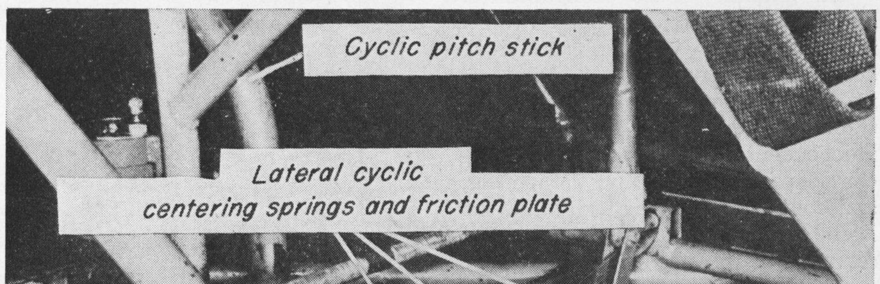


Fig. 3. Control installation details showing a lateral cyclic torque tube.

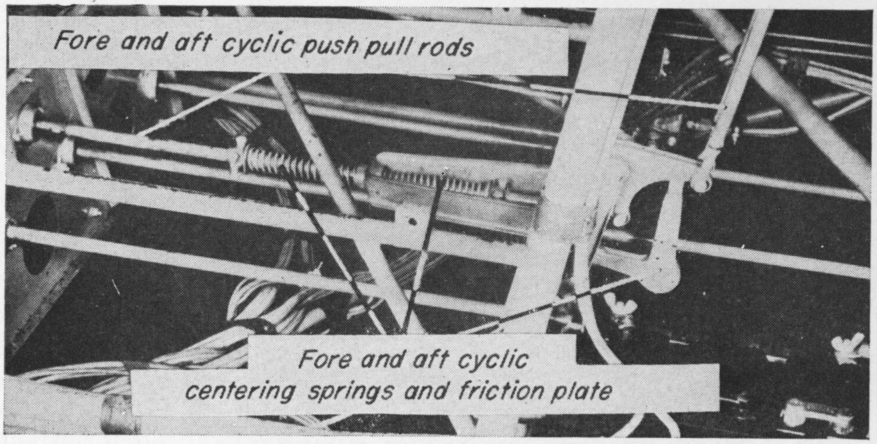


Fig. 4. K-190 control installation detail showing fore-and-aft cyclic push-pull rods.

indicated by theory and later verified by experiment that no perceptible change in control characteristics would be realized with the servo control as compared with the conventional control system.

However, the servo flap mounted to the rear of the rotor blade tends to move the center of pressure of the blade rearward, improving the flutter characteristics of the rotor by producing a stabilizing force similar to that realized between the tail and the main wing of fixed-wing aircraft.

This stability is so pronounced it gives the impression of a rotor system involving large dampening, and it is obtained with no sacrifice in control response. The servo flap represents tremendous actuating force. It acts independently of its inherent spring constant and dampening properties, and control response is instantaneous. Aerodynamic forces acting on the servo flap are negligible and, as a consequence, there are no stick forces.

The servo-flap control has greatly simplified the entire control system and, in eliminating the blade-pitch change bearings, has resulted in the use of a rotor head which is simple in construction, rugged, and inexpensive to manufacture. The rotor hub is a seesaw type employing blade lag hinges. Interblade motion is dampened through the use of friction-type dampers.

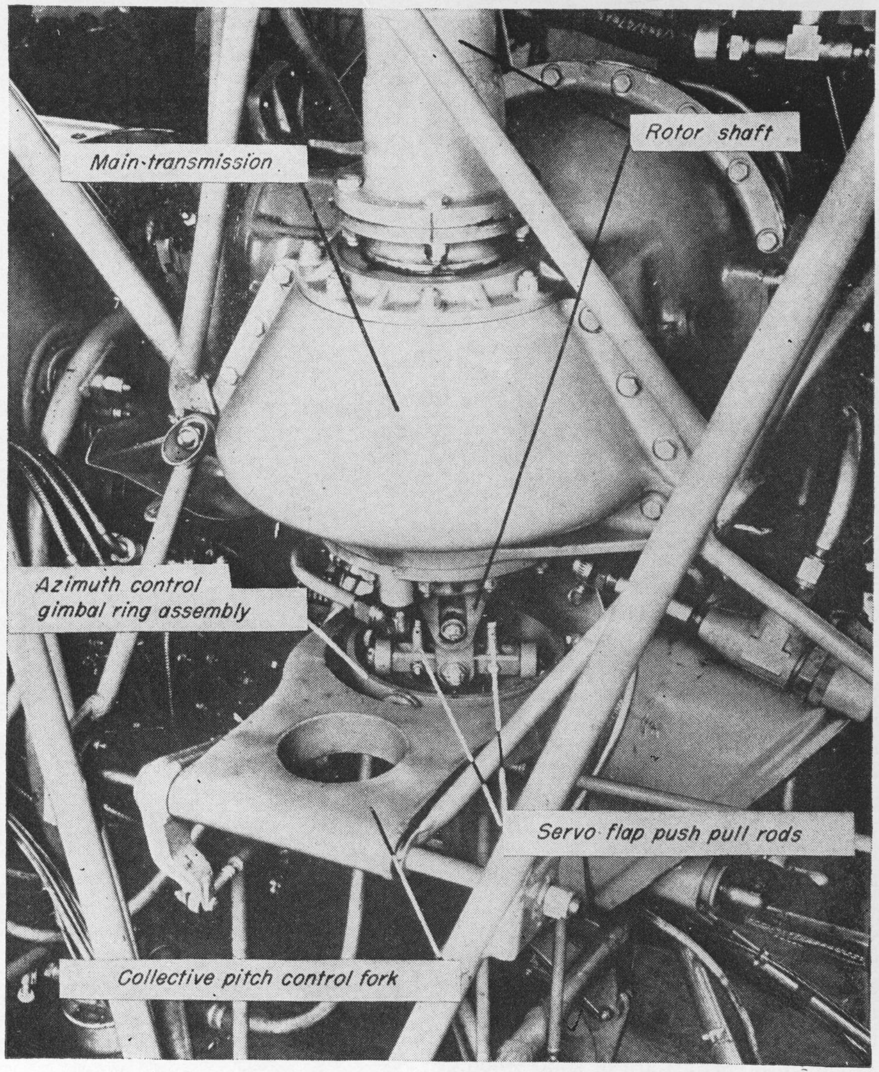


Fig. 5. Rotor control and transmission installation of the K-190.

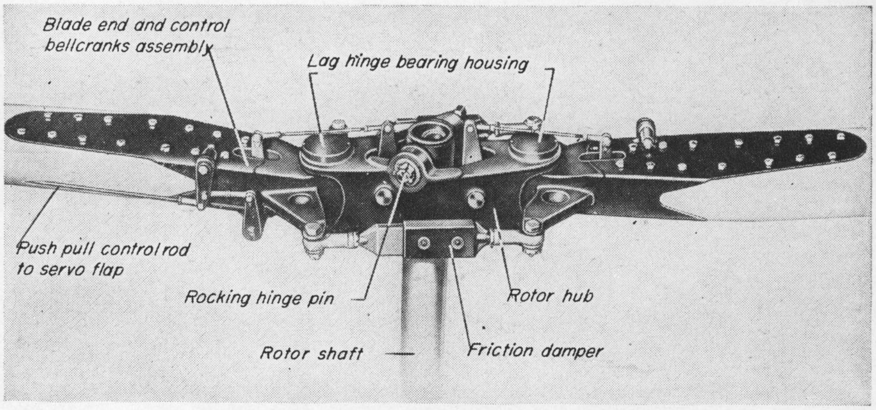


Fig. 6. Kaman rotor hub and blade installation.

PART 3. MISCELLANEOUS DESIGN DETAILS

Bell 47-D Cabin

The plastic bubble (2) used on the 47-D offers the pilot and observer maximum visibility in all directions during take-offs, maneuvers, and landings. Blind areas, caused by frames and other objects that might distract the pilot while executing close maneuvers or approaches to small clearings, are eliminated.

An outstanding feature of the 1948 series helicopter is its ease of conversion from closed- to open-cabin configuration (3) in a matter of minutes without the use of tools. The new convertible plastic bubble-cabin possesses all the desired characteristics for the versatile tasks performed by helicopters.

The upper portion of the bubble as well as the doors can be quickly removed and a small windshield added to the lower portion of the bubble. This windshield is designed adequately to shield the crew from rain and wind at cruising speed.

The open-cabin configuration affords a saving of approximately 28 lb in the weight of the helicopter.

For winter operation, the muff-type cabin heater is installed on the exhaust stacks (1). Warm air supplied by the heater enters the cabin at a point midway between the seats. Each cabin door is provided with an adjustable ventilator.

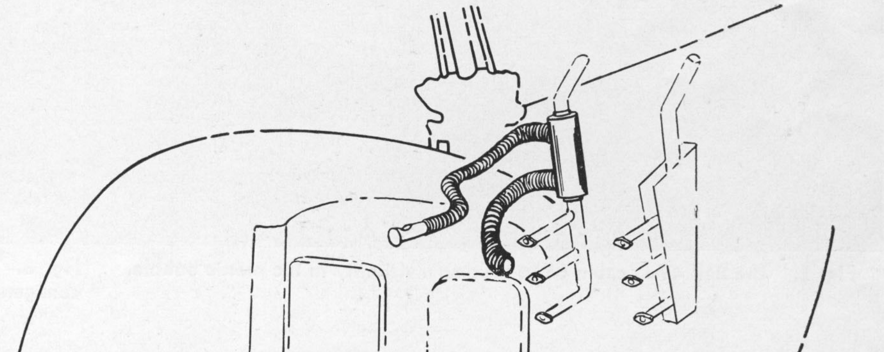


Fig. 1. The cabin heater for the Bell 47-D is installed on the exhaust stacks and supplies warm air at a point midway between the seats.

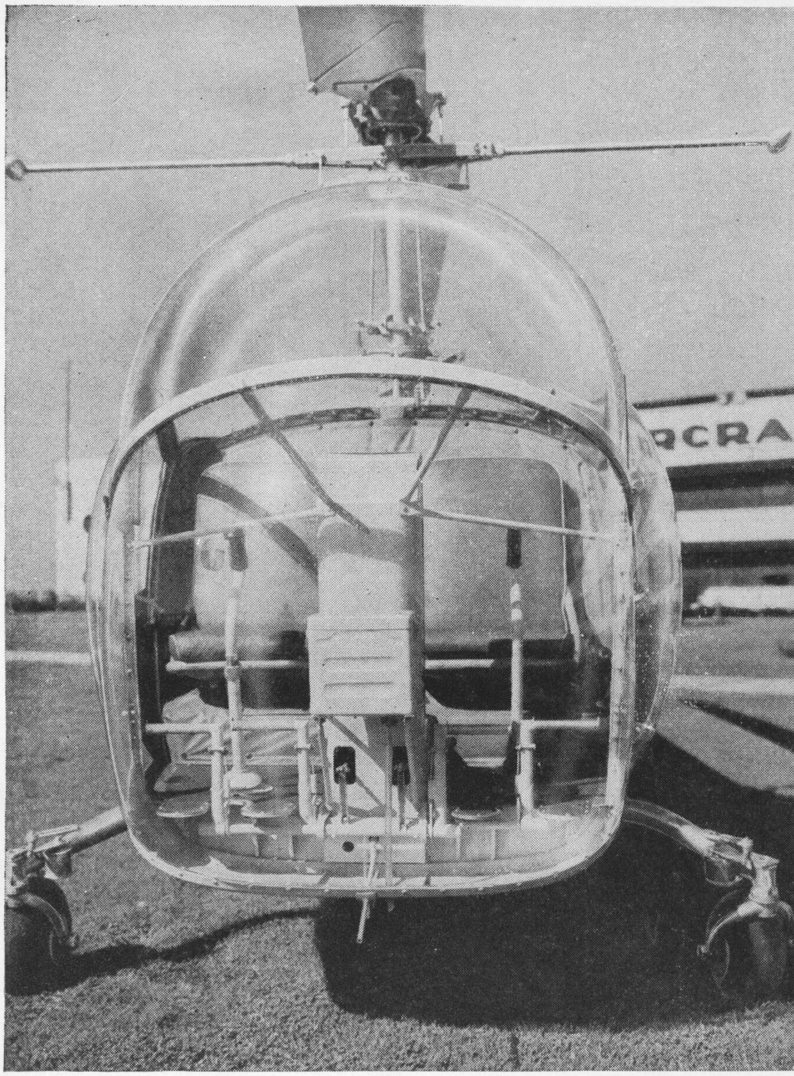


Fig. 2. The Bell 47-D cabin offers maximum visibility in the plastic bubble.

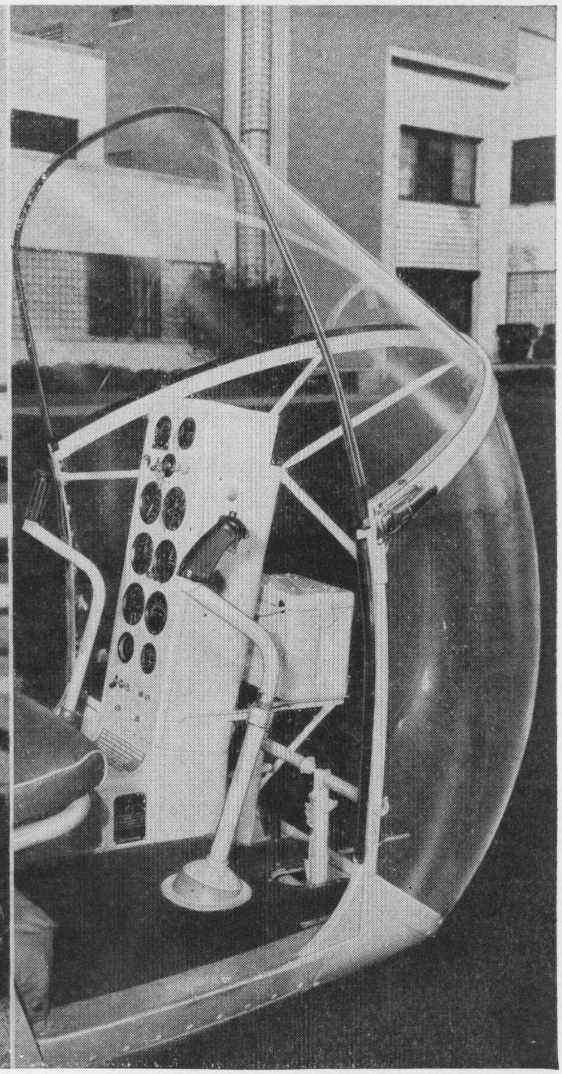


Fig. 3. Ease of conversion from closed- to open-cabin configuration is one of the outstanding features of the 47-D.

Firestone XR-9B

The XR-9B engine is located behind the cockpit. Access panels designed to speed inspection and maintenance of controls and power plant are provided (4). The controls include simultaneous pitch-control stick, fuel primer, longitudinal- and lateral-control stick, and directional control pedals (2).

The fuel system (3) includes fuel tank, fuel pump, primer to cylinders, primer pump, carburetor, engine gauge, fuel-quantity gauge, fuel gauge pump, mixture lever, and lever-actuating wobble pump.

The landing gear is tricycle type with steerable nose wheel. Both main and nose gears are equipped with tow hooks (1).

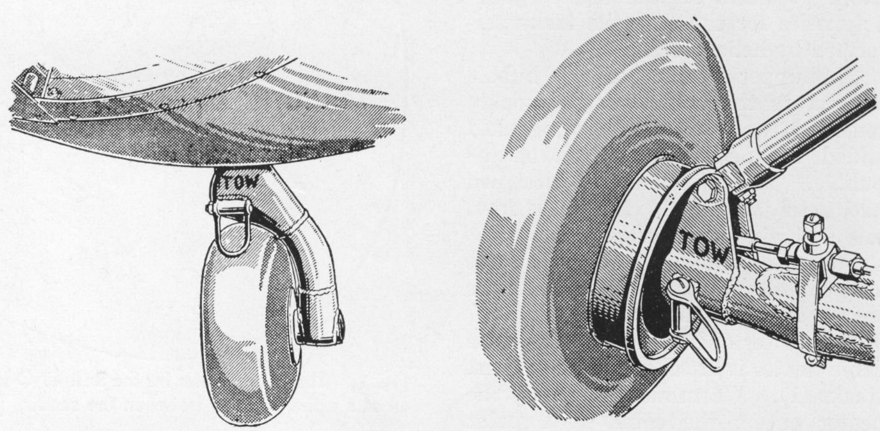


Fig. 1. Close-up sketches of the Firestone XR-9B helicopter, showing details of the landing gear steerable nose wheel with its tow hook (*a*), and main gear with its tow hook (*b*).

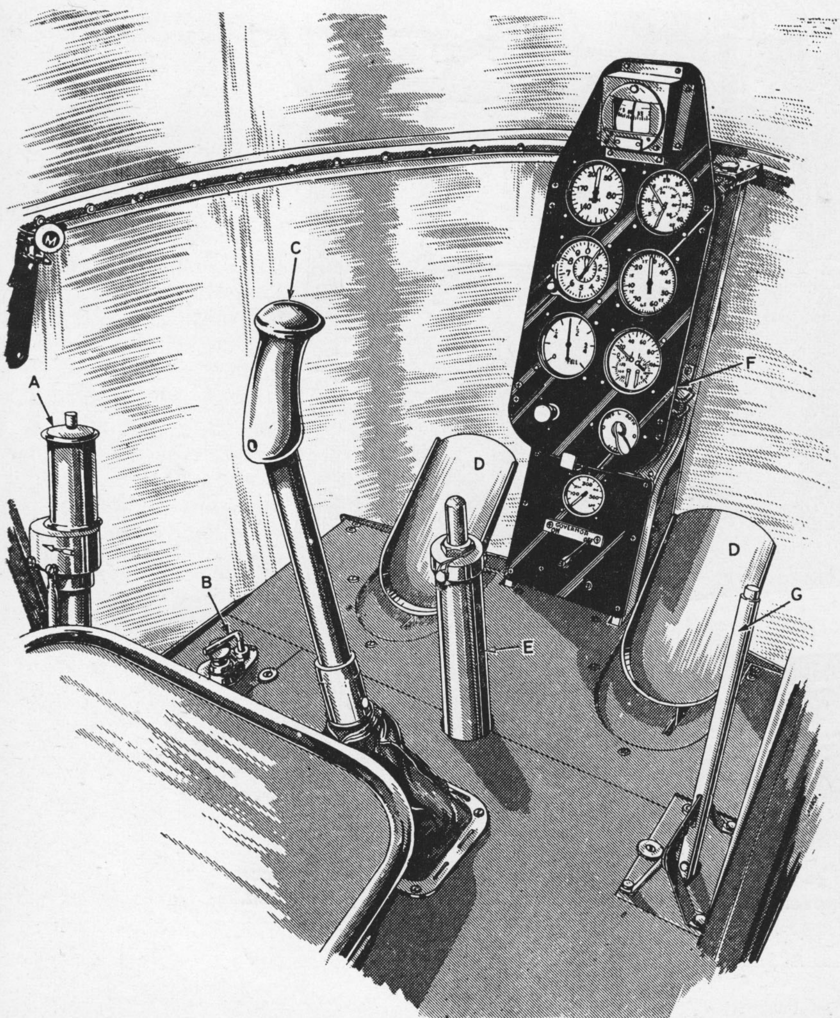


Fig. 2. View over the front pilot's seat in a Firestone XR-9B helicopter. Simultaneous pitch-control stick is at *A*, fuel primer at *B*, longitudinal- and lateral-control stick at *C*, directional control pedals at *D*, nose-wheel reservoir and strut at *E*, instrument panel at *F*, and parking brake at *G*.

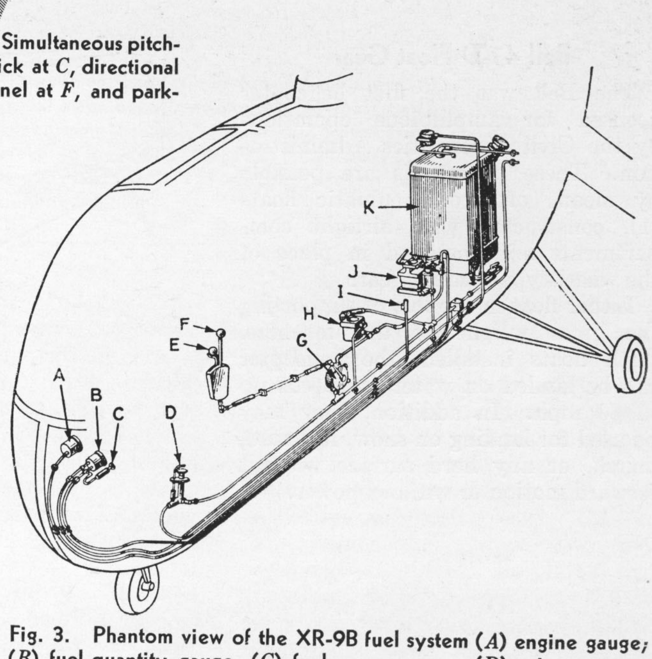


Fig. 3. Phantom view of the XR-9B fuel system (*A*) engine gauge; (*B*) fuel-quantity gauge; (*C*) fuel gauge pump; (*D*) primer pump; (*E*) mixture lever; (*F*) lever to actuate wobble pump; (*G*), (*H*) fuel pump; (*I*) primer to cylinders; (*J*) carburetor; (*K*) fuel tank.

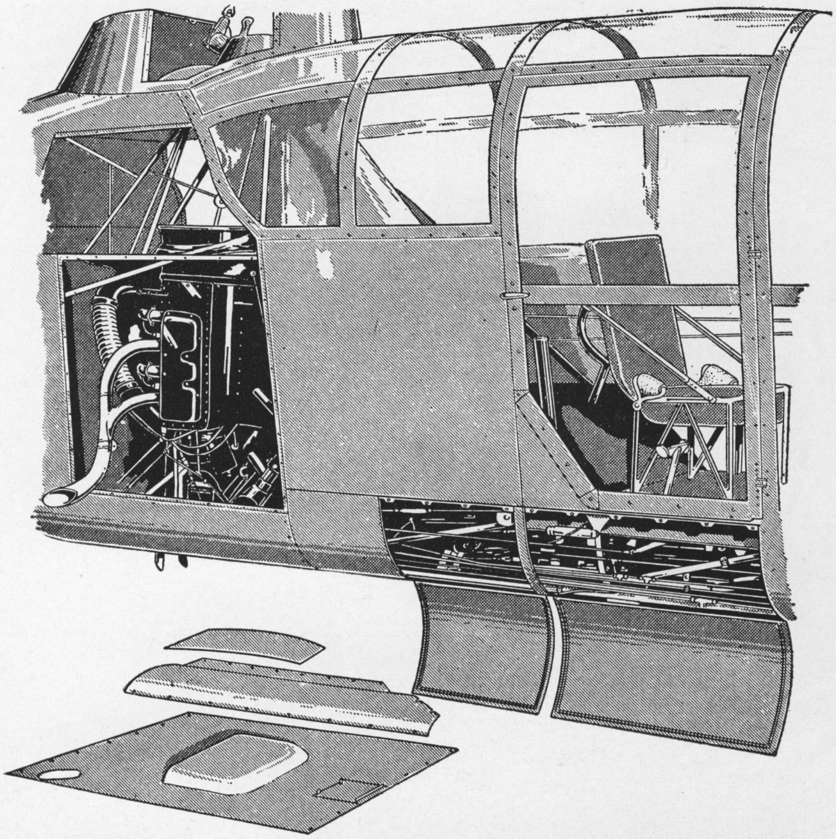


Fig. 4. Close-up sketch of part of the XR-9B helicopter, showing the arrangement of access panels designed to speed inspection and maintenance of controls as well as the power plant.

Bell 47-D Float Gear

The Bell was the first helicopter licensed for amphibious operations by the Civil Aeronautics Administration. These operations are possible by means of two pneumatic floats (1), constructed with airtight compartments and installed in place of the wheel-type landing gear.

Either float is capable of supporting the gross weight of the machine. With floats installed, the helicopter can be landed on water at speeds up to 60 mph. In addition, they may be used for landing on snow, ice, mud, marsh, or any hard surface without forward motion or without power.

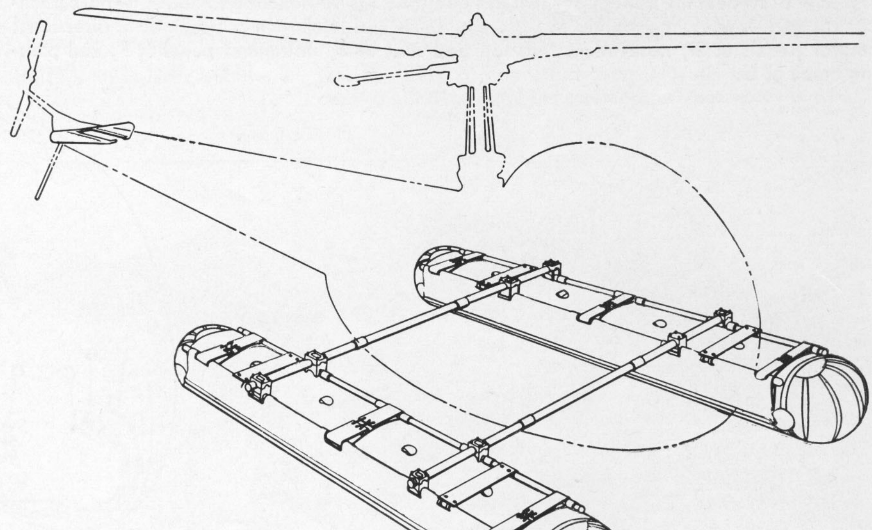


Fig. 1. The pneumatic floats are attached to the Bell helicopter at four points each to two cross bars attached to the fuselage.

Chapter XI. TURBINE ENGINES

PART 1. GENERAL DESIGN CHARACTERISTICS

General Electric TG-180 Turbojet

General Electric initiated TG-180 development in May, 1943, at the request of Air Matériel Command, the first test flight of the turbojet being made in Republic's XP-84 in February, 1946.

An axial flow type, the TG-180 (1)* is installed in a variety of the latest military aircraft—bombers, fighters and transonic research aircraft—as well as in other, undisclosed types.

The design load factor of the engine is 8G's, with permissible ultimate of 12G's, without failure. This load has been stimulated for certain critical assemblies by factory test of the complete engine while operating at full thrust.

* The numbers in parentheses refer to the illustrations.

FUNDAMENTAL DATA

Diameter, max	36¾ in.
Length, max	166 in.
Weight:	
Including all accessories, avg	2,380 lb
Guaranteed max	2,450 lb
Thrust:	
15 min take-off and military rating, avg	4,125 lb
Guaranteed min	3,750 lb
Max. continuous rating, avg	3,420 lb
Rpm (take-off and military)	7,700 lb
Exhaust gas temperature, max	1250°F
Specific fuel consumption (avg. cruise)	1.026 lb/hr/lb thrust
Fuel:	
Gasoline	ANF28
Kerosene	ANF34
Lubricant:	
Hydraulic fluid	3606
Engine oil	1065

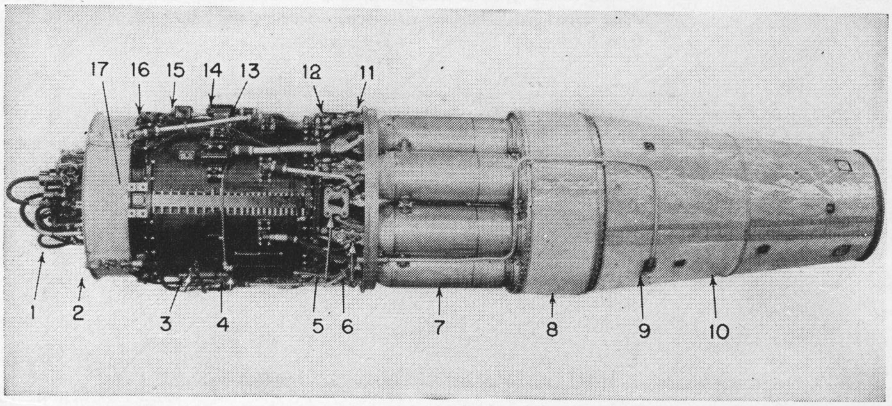


Fig. 1. Left side view of TG-180 showing (1) engine accessories; (2) forward air guide; (3) flow divider; (4) ignition transformer; (5) horizontal main mounting trunnion; (6) fuel nozzle connection; (7) combustion chambers; (8) turbine casing assembly; (9) turbine wheel cooling air line; (10) exhaust cone assembly; (11) engine fire-wall baffle; (12) mid-frame; (13) thrust balancing pressure line; (14) bearing cooling air filter; (15) electric junction box; (16) forward frame; (17) horizontal forward mounting trunnion.

Rolls-Royce Nene Turbojet

The design of the Nene gas turbine (1), similar in outward appearance to the General Electric I-40, around a double- instead of the single-sided impeller used by the Halford-de Havilland Goblin, was dictated by the belief that a greater quantity of air can be consumed for a given frontal area. Use of the double-sided impeller, Rolls-Royce engineers maintain, means that it can be 40 per cent smaller in engine diameter for the same air consumption and thrust.

Nine through-flow combustion chambers are provided. Together with the two-sided compressor, the cooling fan and single-stage turbine are all on one shaft. The exhaust assembly consists of nozzle, cone, and jet pipe. Mainly double-skinned, space between skins is filled with heat-insulating material. A conical fairing inside the nozzle is supported by four long, transverse bolts inside streamlined fairings.

The accessory case is attached, as in the I-40, to the front of the unit just forward of the air intake. Driven at 0.41 engine speed, it contains drives for aircraft accessory gearbox, two fuel pumps (right side), tachometer generator (top), and starter motor (left side).

A wet sump is used in the lubrication system, marking a departure from previous Rolls-Royce practice. Most of the lube oil is contained in a sump formed by the lower part of the accessory gear-drive case. Pressure- and scavenge-oil pumps, two gauze scavenge-oil filters, Purolator high-pressure filter, pressure relief valve, and deaerater are housed in this sump.

The principal specifications and data of the Nene are: thrust, static

(sea level), at 12,300 rpm, 5,000 lb; at 200 mph, 12,300 rpm, 4,620 lb; at 400 mph, 12,300 rpm, 4,390 lb; at 600 mph, 12,300 rpm, 4,450 lb; cruise 100 mph, 11,500 rpm, 3,620 lb; 300 mph, 11,500 rpm, 3,220 lb; 500 mph, 11,500 rpm, 3,070 lb. Temperature, combustion chamber inlet (increase), 200°C; temperature, combustion chamber (increase), 1,150°K; temperature drop, turbine, 175°C; temperature, jet pipe, 702°C.

The dimensions are: length, over-all to exhaust cone flange, 96.8 in.; exhaust cone removed, 63.9 in.; maximum diameter, 49.5 in. Weight (including accessories but without aircraft accessories or jet pipe), 1,550 to 1,600 lb.

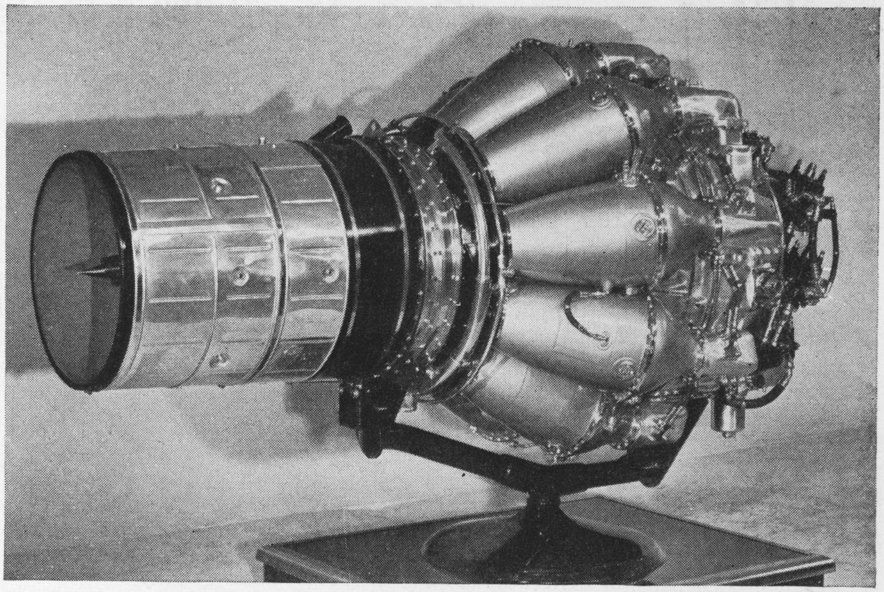


Fig. 1. Distinctive features of the Rolls-Royce Nene are the two-sided compressor around which the engine is designed, and the wet sump used in the lubrication system, a departure from usual Rolls-Royce practice. The power plant has a superficial similarity in appearance to the General Electric I-40 gas turbine.

Junkers Jumo-004 Turbojet

The Jumo-004 turbojet (1) is a large axial flow unit, 152 in. in length from intake to exhaust tip; 30 in. in diameter at the skin round the six combustion chambers, with the maximum diameter of the cowling reaching 34 in.

The circular nose cowling is double-skinned, the two surfaces being welded together near the leading edge and held in position by riveted channel-shaped brackets. Diameter at the intake end is 20 in., the outer skin increasing to 31½ in., the inner to 21½ in.

General Data

Weight, lb:	
Without cowl	1,669
With cowl	1,775
Specific	0.85
Thrust, lb	1,970–1,980
Pressure ratio	3:1
Fuel consumption, lb/hr	2,720–2,745
Specific fuel consumption	1.375–1.39
Speed, rpm:	
Max	8,700
Idling	3,080
Idling speed fuel consumption, lb/hr	614
Frontal cowl area, sq ft	6.4

Basic and Accessories Weights, Pounds

Casting with oil pumps, filter	57
Bevel gear assembly and drive shafts	18
Gearbox and drive	35
Front compressor bearing assembly	25
Total for intake	135
Stator casting and blades	200
Rotor with stub shaft and tie rod	220
Center section main casting and fittings	163
Upper casing and fittings	100
Rear compressor bearing assembly	6½
Front turbine bearing assembly	7½
Rear turbine bearing assembly and scavenge pumps	9
Total	286
Total combustion chambers, igniters, and interconnectors (six)	116
Turbine inlet ducting and joint rings	42
Nozzle assembly	43
Diaphragm plates	10
Disk and blades (solid)	151
Shaft, sleeve, fittings	30
Compressor coupling	7
Total	283
Exhaust bullet assembly	190
Total, without accessories	1,430

Accessories

Oil tank	27
Fuel pump	9
Governor	17
Tachometer	1½
Air-oil separator	4
Bullet control servo motor	17½
Drive shaft for bullet	4
Fuel filter	2
Fuel no-return valves	1
Throttle linkage	7
Miscellaneous fittings and attachments	25
Total	115
Engine-mount brackets	15
Starter engine	36
Gasoline tanks and supports	20
Gasoline pump	6
Igniter coils	3
Total starter weight	65
Net dry weight with starter	1,625
Generator fittings	36
Hydraulic pump	8
Total	44
Starter engine cowling	4
Starting fuel tank cowling	17
Remainder of cowling	85
Total cowling weight	106
Total dry weight, completely cowled engine	1,775

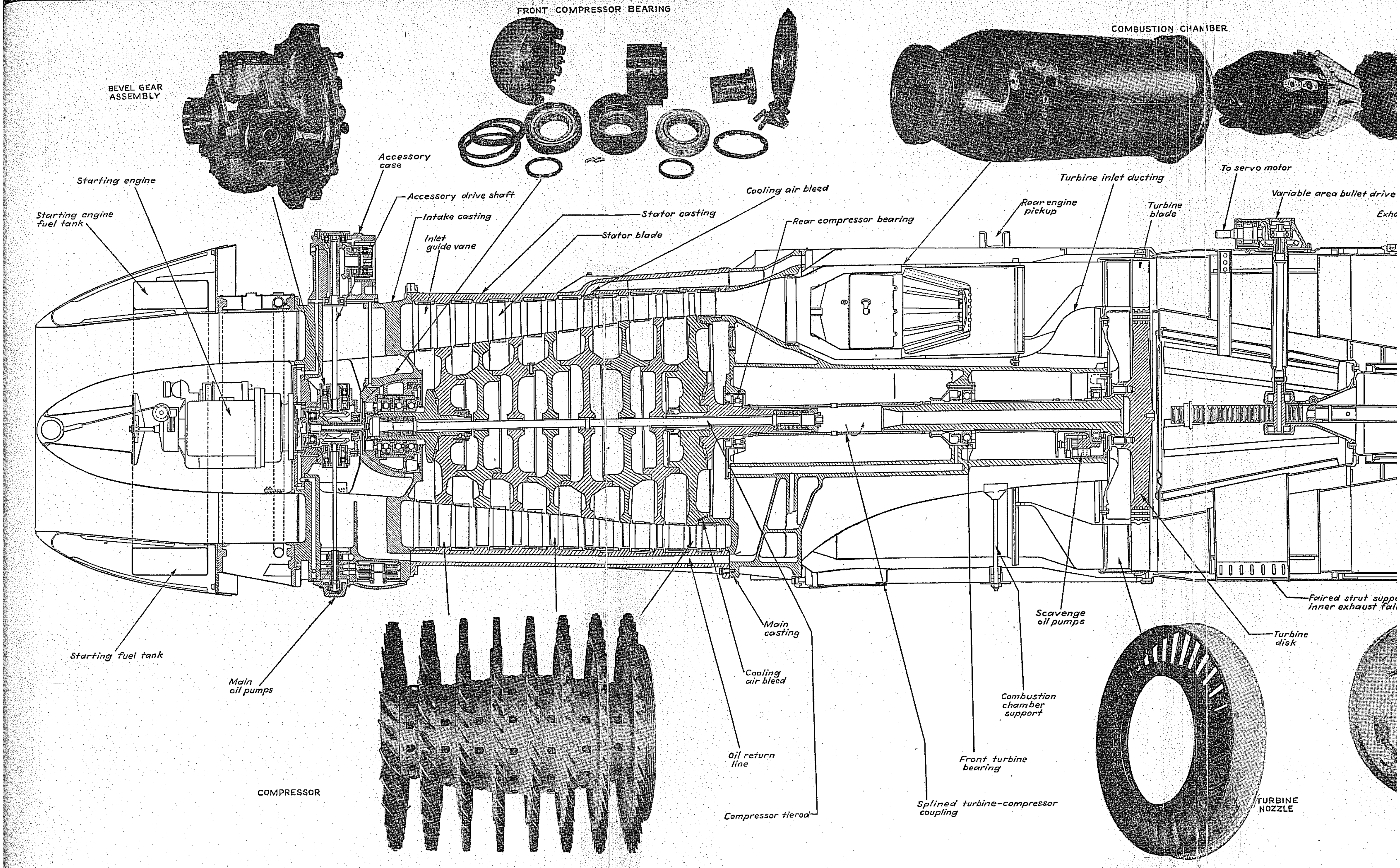


Fig. 1. Principal components and longitudinal section view of the Jumo-004 turbojet.

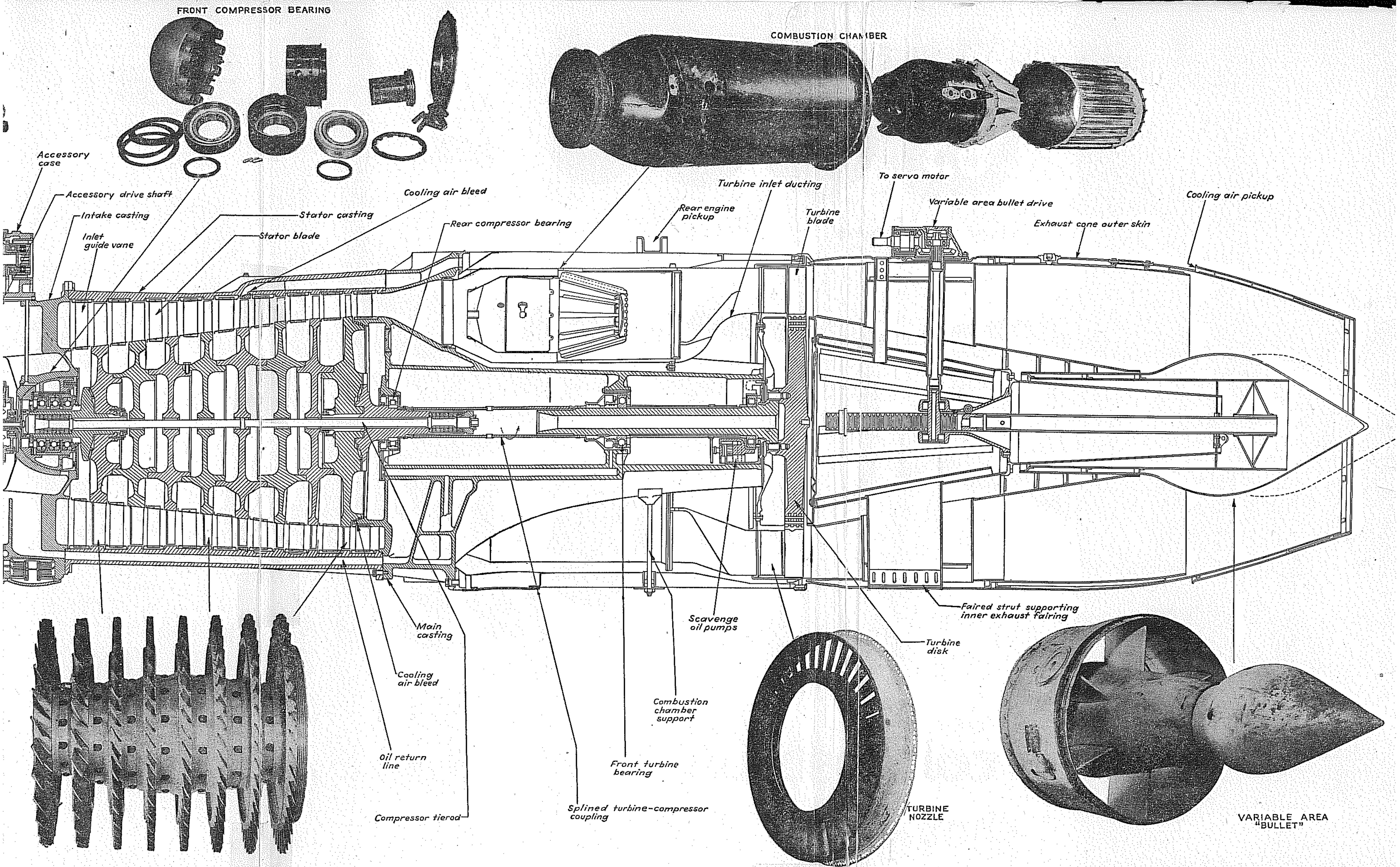


Fig. 1. Principal components and longitudinal section view of the Jumo-004 turbojet.

General Electric I-16 Turbojet

The GE I-16 (Air Force J-31) turbojet (1) is a complete power package, weighing 825 lb with all attached accessories and having an installed weight of about 1,054 lb. Specifications are as follows: impeller, 20.69 in.; diffuser throat area, 30.6 sq in.; turbine nozzle area, 54 sq in.; turbine pitch diameter, 14.2 in.; turbine nozzle and blade height, 2.76 in.; exhaust pipe diameter, 14.4 in.; jet nozzle diameter, 12.4 in.; maximum over-all diameter, 41.5 in.; over-all length, 70 in.; average weight, 825 lb; c.g. (aft of trunnion), 8.5 in.

The I-16 is rated at 1,650 lb static sea-level thrust at 16,500 rpm with a tail-pipe temperature of 1180°F, and specific fuel consumption of 1.18. It was the first satisfactory American model to be released for quantity production.

A centrifugal type, the I-16 has a single-stage turbine and 10 counterflow combustion chambers. The centrifugal air compressor is a double-sided multiple-vaned wheel (impeller) enclosed in a casing, together with a diffuser.

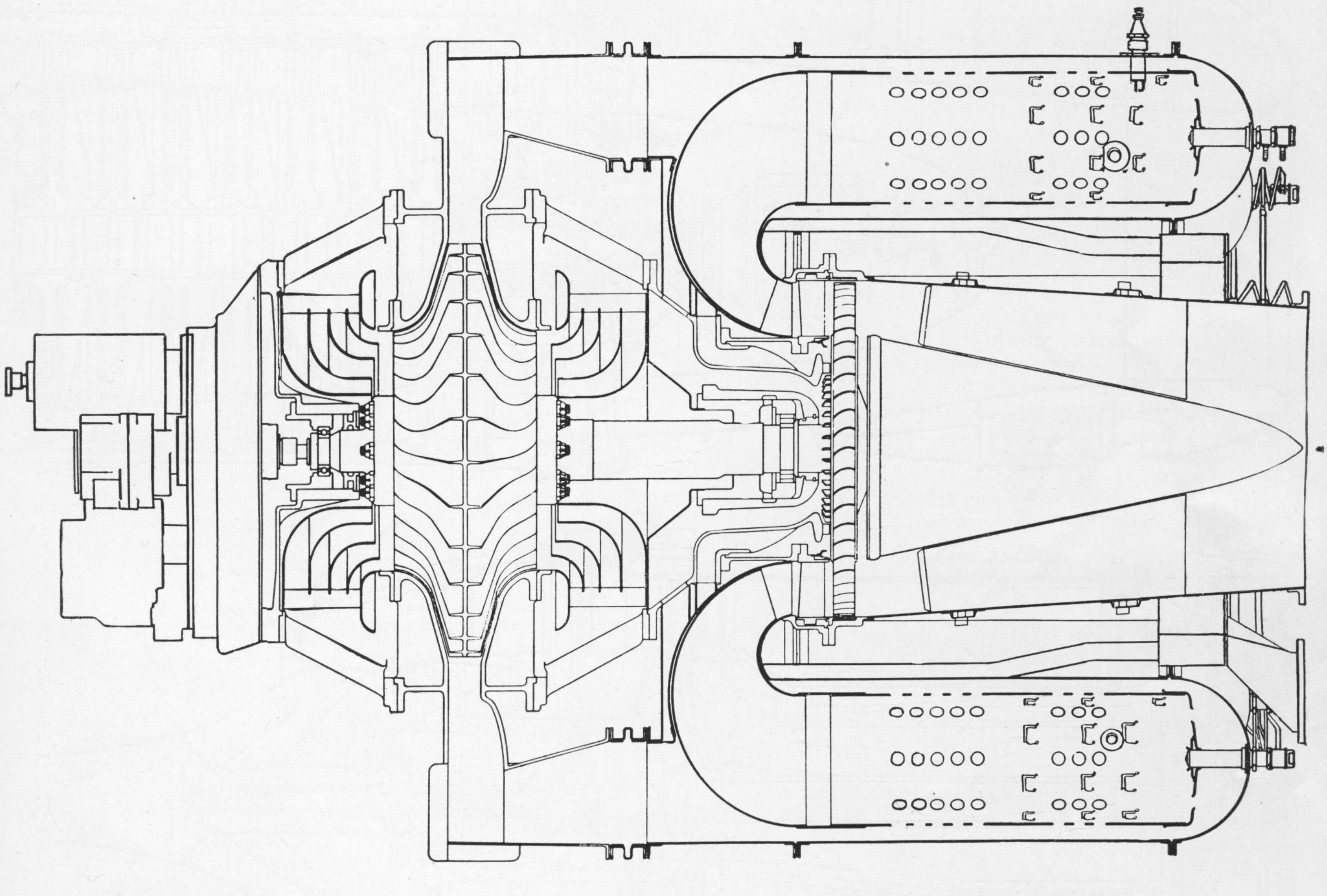


Fig. 1. Flow diagram of an I-16 turbojet engine built by General Electric.

BMW-003 Turbojet

The major components of the BMW-003 A and C jet engine models, built by the Bayerische Motorenwerke, Munich, consist of an inlet duct which guides ram air into the compressor; a seven-stage axial-flow compressor serving to compress this air to about 3.5 atm; an annular combustion chamber, containing 16 fuel nozzles, where compressed air is heated by the combustion of fuel; a turbine assembly, consisting of turbine nozzles and turbine wheel, which drives the compressor and accessories; and an adjustable tail cone located aft of the turbine, providing the desired thrust at all times while maintaining the temperature of gases at the turbine wheel below the maximum allowable (1).

These models have a static thrust (sea level) of 1,760 lb at 9,500 rpm, and 1,980 lb at 9,800 rpm. Performance for the 003A is 560 mph at sea level, 1,555 lb thrust; 560 mph at 32,000 ft, 695 lb thrust. Specific fuel consumption is 1.47 to 1.40 lb per lb per hr.

Weight of the power plant is 1,342 lb; diameter, 27.1 in.; length, 124 in.

The 003D is an eight-stage axial-flow compressor type with a two-stage

turbine, annular combustion chamber, and adjustable tail cone. Static thrust at 10,000 rpm is 2,420 lb. Specific fuel consumption is 1.10 lb per lb per hr. Weight is 1,430 lb; diameter, 27.1 in., and length, 124 in.

The 003R model consists of 003A through D gas turbine plus a rocket unit of 2,750 lb thrust.

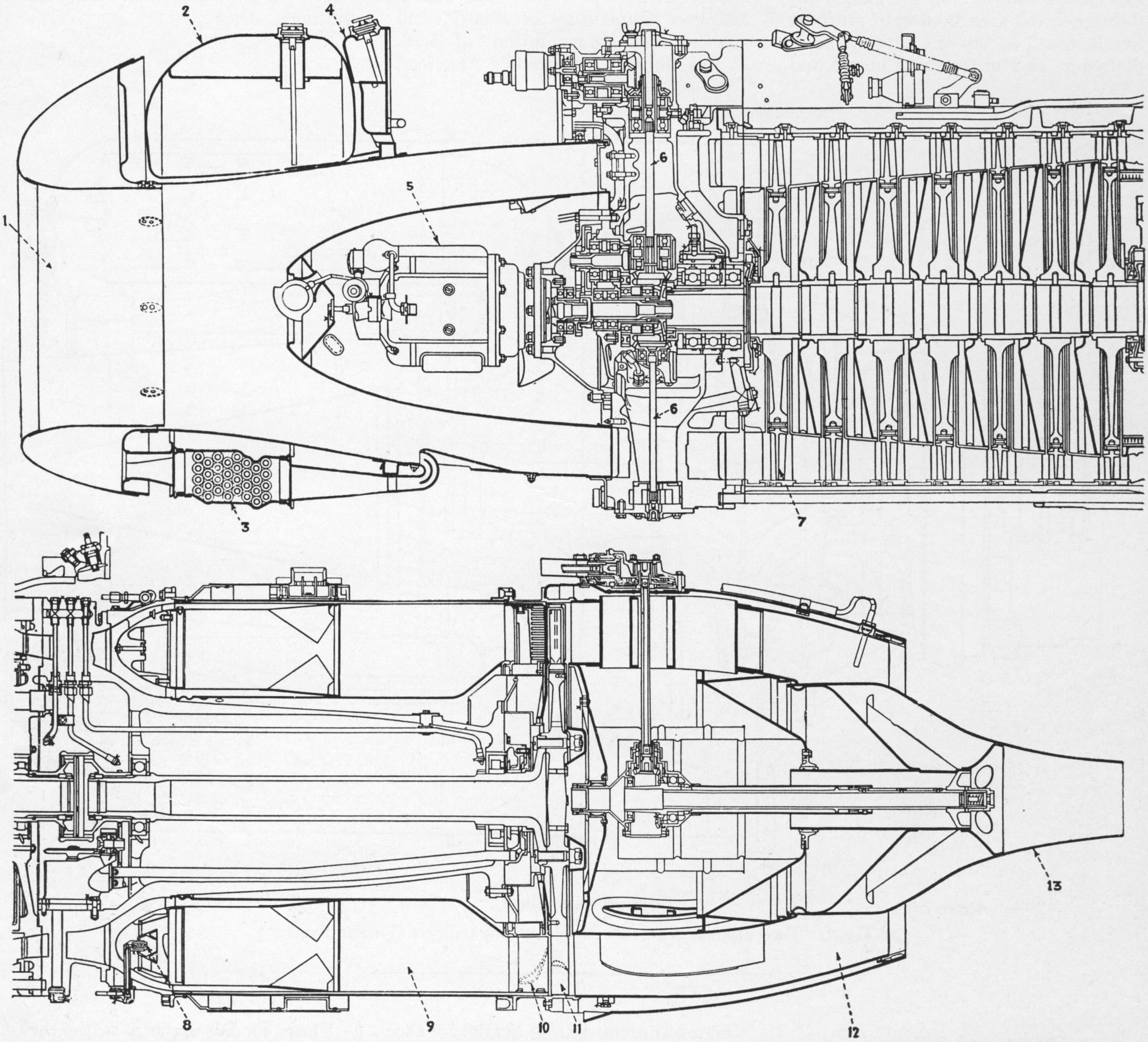


Fig. 1. Sectional view of the BMW-003 jet showing: (1) air intake; (2) oil tank; (3) oil cooler; (4) starter fuel tank; (5) starter; (6) auxiliary drive shafts; (7) compressor; (8) fuel injection nozzle; (9) combustion chamber; (10) turbine nozzle; (11) turbine wheel; (12) thrust nozzle; (13) adjustable tail cone.

Westinghouse Yankee 19-B Turbojet

One of the prime requirements under which the Westinghouse 19-A and -B turbojet engines were developed, the first all-American designed gas turbines, was a small frontal area. This requirement of the Navy made it natural to select the axial flow-type compressor.

Aside from the aerodynamic need, however, is the fact that a greater mass of air can be moved through the engine. In the 19-B, for example, the air takes less than 0.02 sec to pass from the intake, through the compressor, into the combustion chamber, through the turbine nozzle and turbine, and out through the exhaust cone.

On the 19-B (1) the annular aluminum oil cooler (2) is bolted by a flange to the leading edge of the intake casting-front bearing support. Thus the oil can be cooled even when the aircraft is stationary on the ground.

The major subassemblies of the Yankee are the oil cooler; inlet and front bearing support; compressor; combustion chamber; and exhaust nozzle (3).

General specifications of the 19-B are as follows:

PERFORMANCE

Thrust, lb:	
Static sea level, 1500°F turbine inlet temperature	1,365
500 mph, 1500°F inlet temperature	1,125
Air flow, max., lb/sec:	
Static sea level	28
500 mph	38
Temperature at turbine nozzle:	
Max	1500°F
Normal	1200°F

DIMENSIONS, INCHES

Length, tail cone out:	
With oil cooler	104 15/32
Minus oil cooler	80 15/32
Diameter:	
Basic	19
Max	20 3/4
C.g., forward of mounting lugs	2

WEIGHTS, POUNDS

Dry weight:	
Power plant	765
Oil cooler	20
Generator	35
Hydraulic or vacuum pump	6
Total dry weight	826
Oil (3 gpm)	21
Total installed weight	847

CLEARANCES, INCHES

Bearings:	
No. 1, radial	0.005
No. 2, axial:	
Thrust face	0.000
Unloaded face	0.008
Radial	0.005
No. 3, radial	0.005
All bearing seals	0.008
Compressor:	
Axial between rotor and stator blades	3/32
Axial between inlet guide vane and first compressor stage	1/8
Radial between rotor blade tips and casing	0.030
Radial between stator shroud seal and rotor land	0.030
Radial between straightener vane seal and rotor land	0.020
Turbine:	
Axial between nozzle inner shroud ring turbine disk	1/4
Axial between turbine disk and tail cone assembly	1/4
Radial blade tips and exhaust cone shell	0.0625
Nozzle vanes, loose fit, cold, clearance in shroud ring slots	0.010
End play	1/32

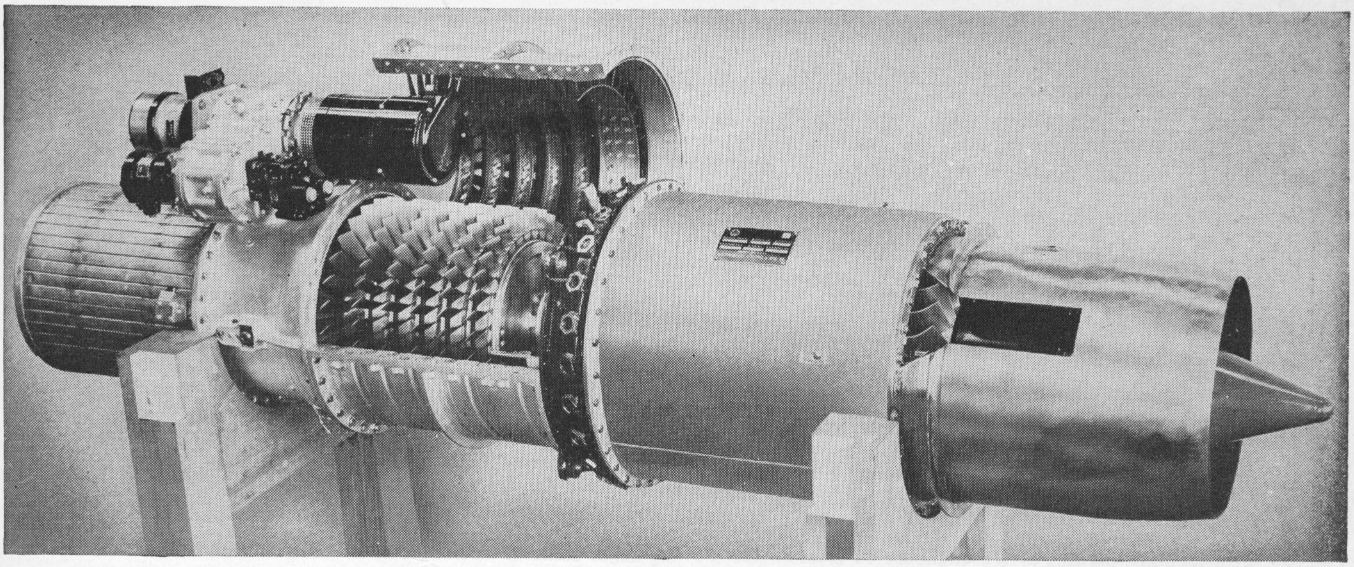


Fig. 1. The Westinghouse Yankee 19-B is characterized by its small frontal area and the annular aluminum oil cooler attached to the L.E. of the air intake.

Normal Temperatures and Oil Pressures

	At 12,000 rpm	At 18,000 rpm
Turbine inlet temperature	800–1000°F	1000–1200°F
No. 1 bearing oil outlet	90–100°F	110–140°F
No. 2 bearing oil outlet	135–165°F	190–235°F
No. 3 bearing oil outlet	160–190°F	185–215°F
Fuel pump discharge pressure	250–280 psi	
Fuel manifold pressure	30–35 psi	
Oil pump discharge pressure	50–60 psi	90–120 psi

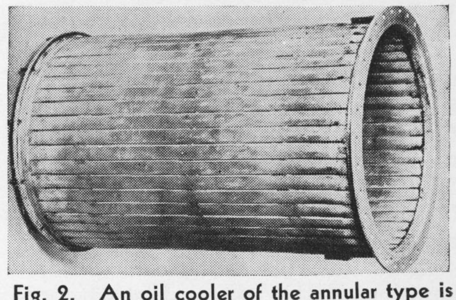


Fig. 2. An oil cooler of the annular type is installed in front of the intake end of the 19-B Yankee, thus assuring cool oil even when the aircraft is stationary and at the same time reducing frontal area.

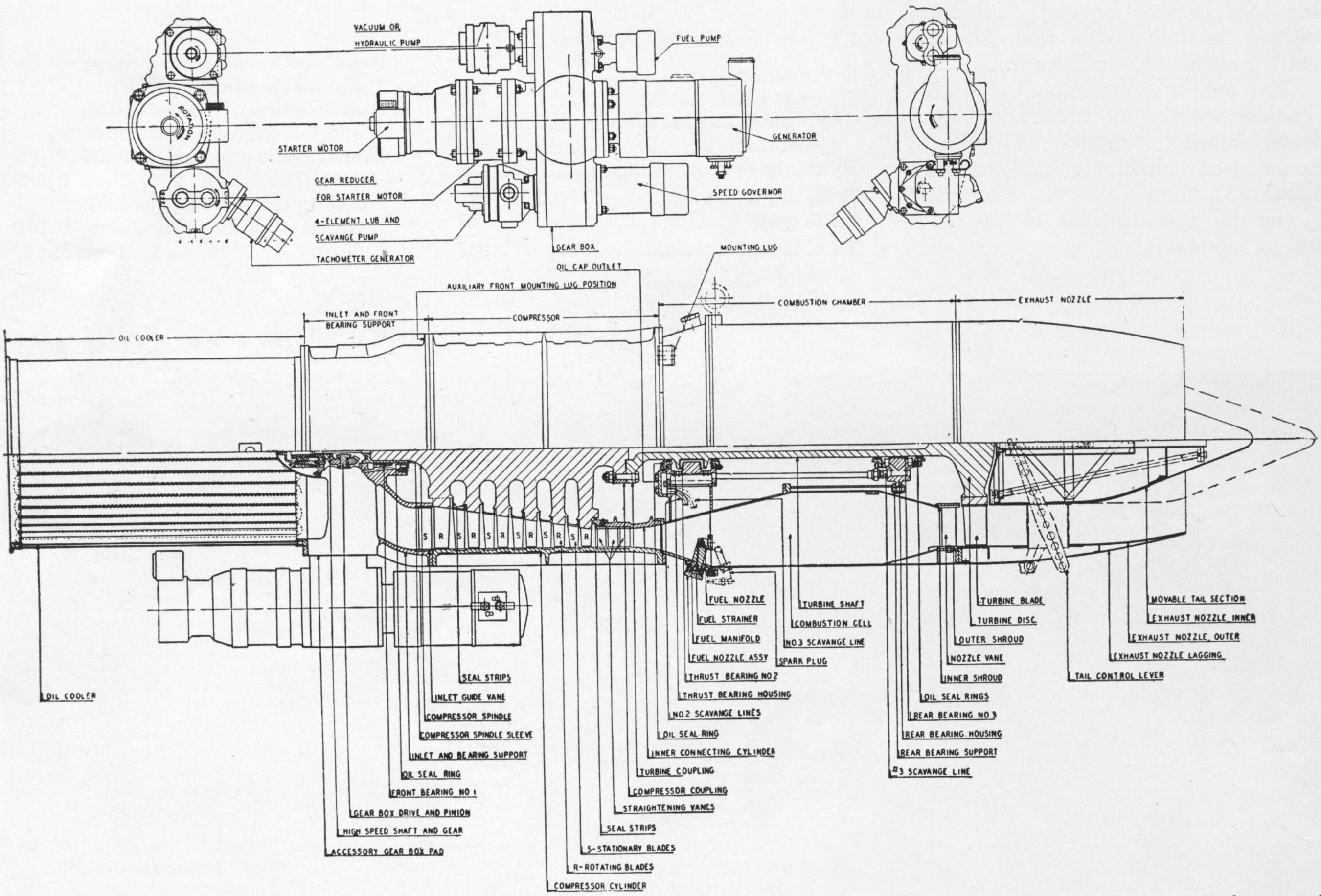


Fig. 3. Cross-sectional drawing of Westinghouse 19-B jet engine showing major units. Accessories in this case are mounted on the bottom of the unit.

Avro Canada Chinook Turbojet

Canada's first jet engine, an axial flow type, was designed and manufactured by A. V. Roe Canada, Ltd., for the Royal Canadian Air Force. Called the "Chinook" (1), the major components of the engine are a nine-stage axial flow compressor, six through-flow combustion chambers, a single axial flow turbine, and an exhaust tail cone.

The maximum over-all diameter is 32.00 in.; maximum radius at auxiliaries gearbox is 17.875 in., and over-all length (nose bullet to tail cone flange) is 125.137 in.

The total weight, including auxiliaries but excluding aircraft accessories, is 1,250 lb.

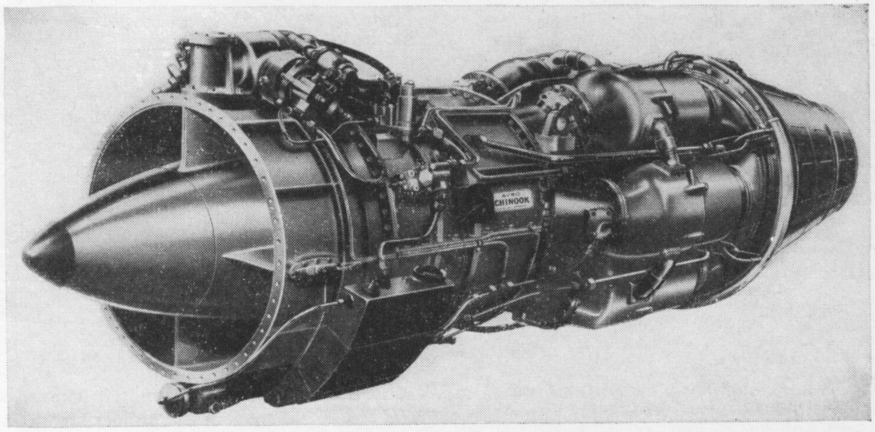


Fig. 1. The Avro Chinook turbojet contains its thrust entirely from the reaction due to the change in momentum of the internal gases.

De Havilland Goblin Turbojet

Featuring a single-sided impeller, and the first turbojet to adopt the straight-through combustion system, the de Havilland Goblin II (1) was rated for production at 3,000 lb of thrust.

The impeller, 31 in. in diameter, has 17 vanes and delivers air to the combustion chambers at a 3.3:1 pressure ratio at a maximum speed of 10,200 rpm.

The single-stage turbine has 83 blades made of Nimonic-80 alloy.

The rotor assembly is supported on front and rear roller bearings, and the hollow rotor shaft is machined from a steel forging and bolted to both impeller and turbine disk.

The 16 flower-pot type combustion chambers (2) are composed of three principal elements: outer casing, flame tube, and burner.

The specifications and data include: thrust, static sea level, 3,000 lb; maximum rpm, 10,200; weight, 1,550 lb; compression ratio, 3.3:1; impeller diameter, 31 in.; combustion chambers, 16.

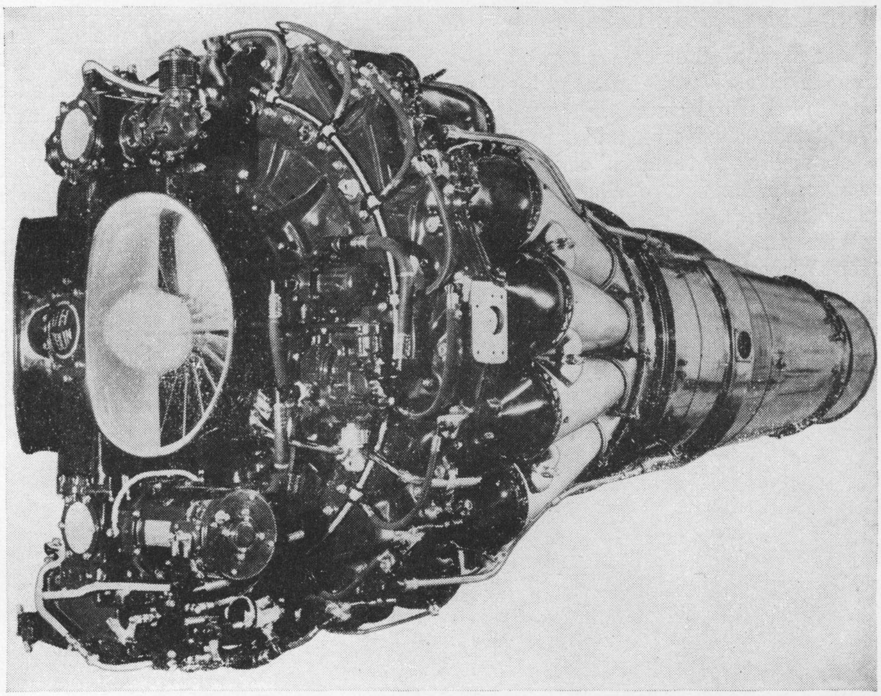


Fig. 1. The Goblin features a single-sided impeller, the main difference between the Halford and other British centrifugal turbojets. This jet was a development of the organization of Major Frank B. Halford which became the de Havilland Engine Company in 1944.

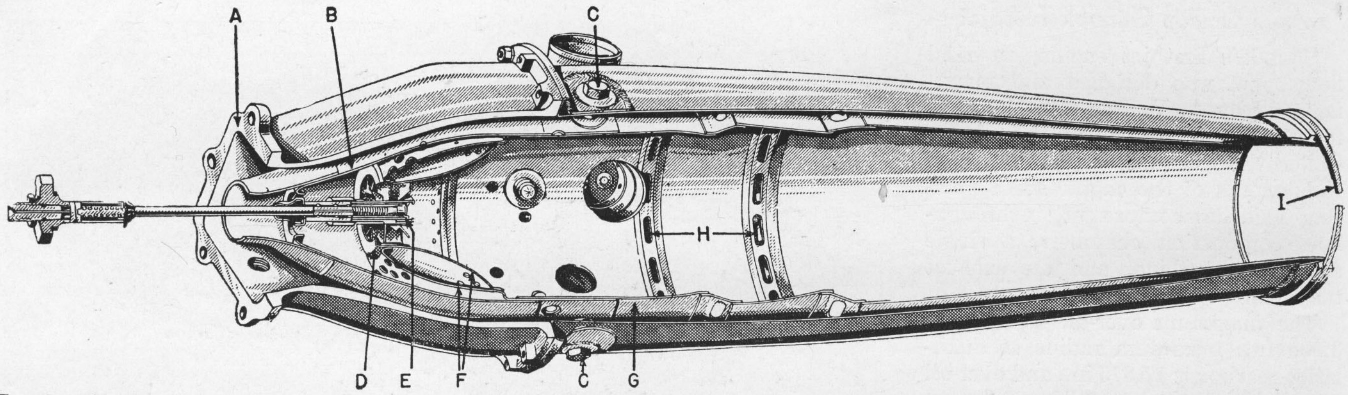


Fig. 2. A cutaway view of the Goblin combustion chamber. The unit bolts to expansion chamber at *A*, upstream end. Concentric flame tube *B* is held in place by three pins—two showing at *C*—that are attached to the outer casing, but allowed to slide in sockets in flame tube for radial expansion. The burner has swirler *D* round the fuel nozzle *E* and metering holes in caps *F* through which about 20 per cent of the air from the compressor enters the combustion chamber. The remaining 80 per cent goes through annulus *G* and is metered into the chamber through ports *H*. The downstream end of the chamber is attached to nozzle junction by expansion joint *I*.

Bristol Proteus Turboprop

The Bristol Proteus turboprop engine (1) consists of an axial and a centrifugal compressor, eight separate combustion chambers, and two separate axial flow turbines driving the compressor and propeller systems, respectively.

With the exhaust cone removed, over-all length is 99.75 in. Over-all diameter is 38.5 in. Net weight (dry) is 2,900 lb; c.g. is 18.5 in. forward of the mounting ring aircraft attachment face.

Turbine/propeller reduction gear ratio is 11.11:1; propeller shaft size is Society of British Aircraft Constructors No. 6—R.S. 267; propeller rotation is left-handed tractor, and compressor rpm is 10,000 maximum.

Using aviation kerosene with a specific gravity of 0.81, sea-level static power is 3,200 shp plus 800 lb thrust. The oil used is Intava 7117 type B (60-sec viscosity).

The Proteus powers both the Bristol Brabazon 1 Mark II, 130-ton landplane, and the 140-ton Saunders Roe SR 45 flying boat. In these aircraft, the Proteus is installed in coupled units, each consisting of two engines arranged with their shafts parallel and driving a coupling gearbox which, in conjunction with a reduction gearbox, drives the coaxial shafts for the contrarotating propellers (2).

Because of the small diameter of the engines and their compact layout, the coupled unit is designed for installation entirely within the wing, the reduction gear and propeller shaft enclosed in a faired stalk projecting forward of the wing.

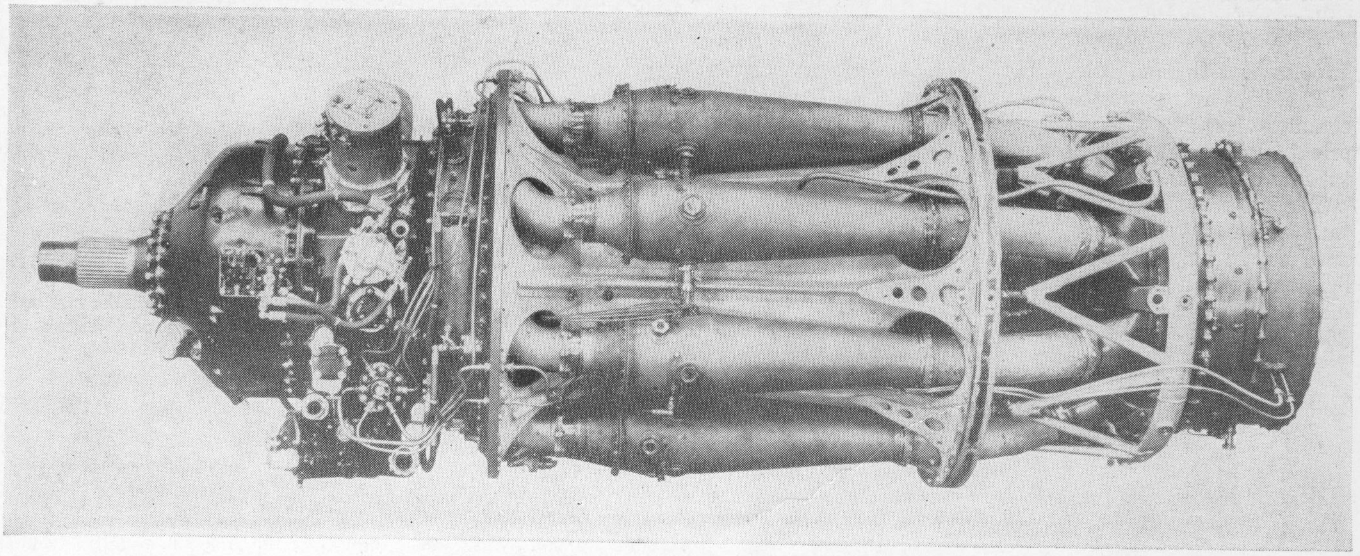


Fig. 1. Side view of the Bristol Proteus propeller turbine.

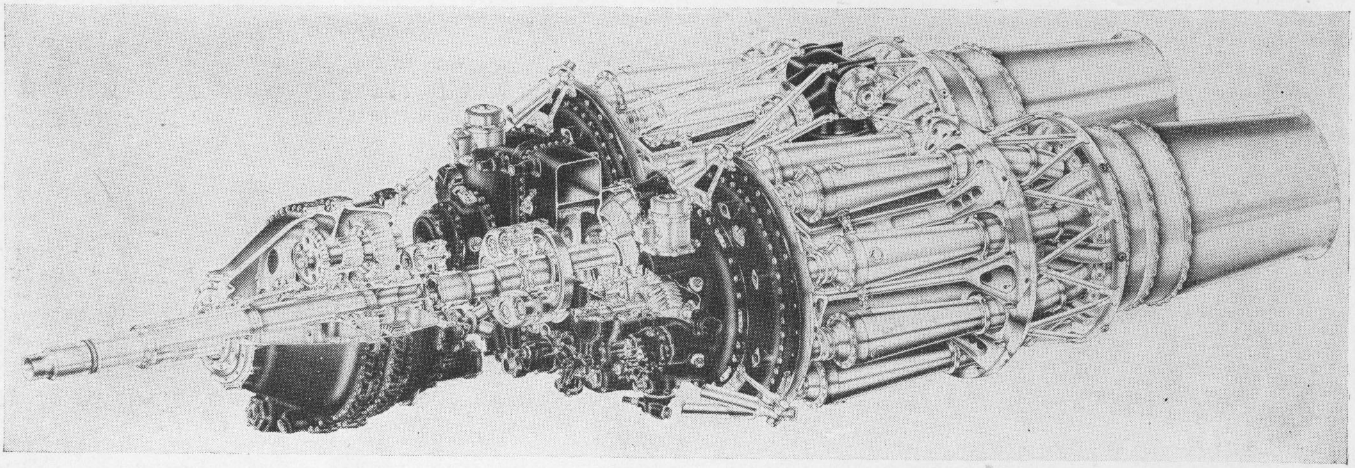


Fig. 2. Cutaway drawing of the coupled Proteus propjet unit designed for installation in the wings of the Brabazon I Mark II landplane and the Saunders Roe SR 45 flying boat.

Wright Turbo-Cyclone 18

Combining a reciprocating power plant with three "blowdown" or velocity turbines which operate on the exhaust gases to recover approximately 20 per cent of the available heat energy normally lost through the exhaust, the Turbo-Cyclone 18 compound engine (1) is said to be able to operate 20 per cent farther for the same fuel consumption in a given airplane than a conventional piston engine.

Conversion of the exhaust gases into power, which is geared back directly to the crankshaft, adds 20 per cent to the horsepower developed by the engine for the same fuel consumption.

Aside from increasing the power, range, and pay-load capacity of existing military and commercial aircraft, the new power plant has the following advantages: (*a*) it operates efficiently over a range from sea level to high altitude; (*b*) its turbines impose a minimum of back pressure on the engine and consequently do not impair the operation of the piston power plant or impose any additional stresses on piston engine parts; (*c*) no additional controls are needed, therefore requiring no special training of pilots or flight engineers; (*d*) the new engine may be installed in existing aircraft because it is adapted to an existing power plant, increases the latter's over-all dimensions by only a few inches, and fits within the cowl lines of existing installations with a minimum of change; and (*e*) its power recovery units act as mufflers without cutting the output of the engine.

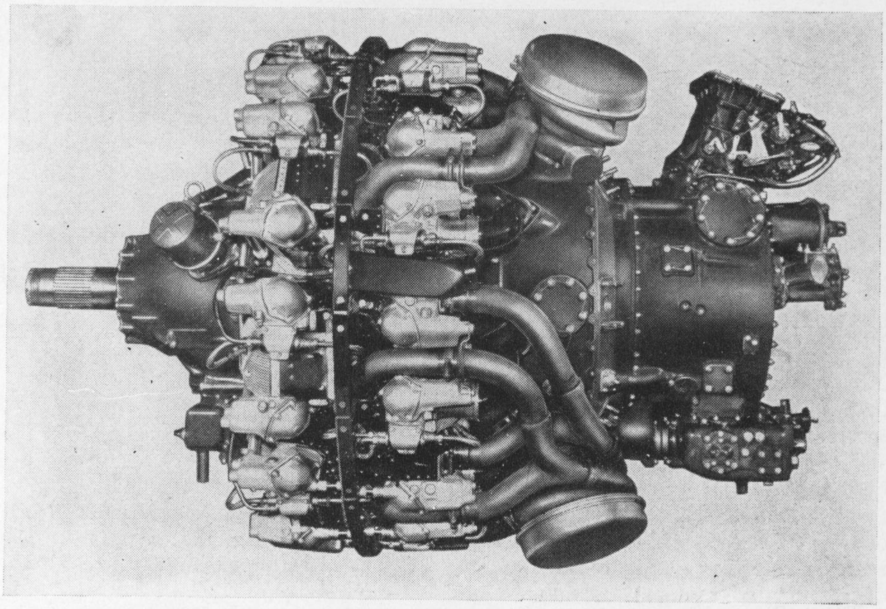


Fig. 1. A side view of the Wright Turbo-Cyclone 18 compound engine, the first power plant of its type to be put into production.

General Electric I-40 Turbojet

The GE I-40 (Air Force J-33) was given its first flight trial in a Lockheed P-80A at Muroc Air Base, Calif., on June 10, 1944, less than a year after the start of the development project. Since then further development has proceeded rapidly.

The mechanical construction of the turbojet, a centrifugal type, consists of five major subassemblies bolted together to form the complete assembly: accessory drive, compressor, turbine and combustion chambers, exhaust cone, air adapters (1).

Each subassembly, which is a complete and operative unit in itself in so far as its particular function is concerned, is interchangeable in all I-40 gas turbines without matching,

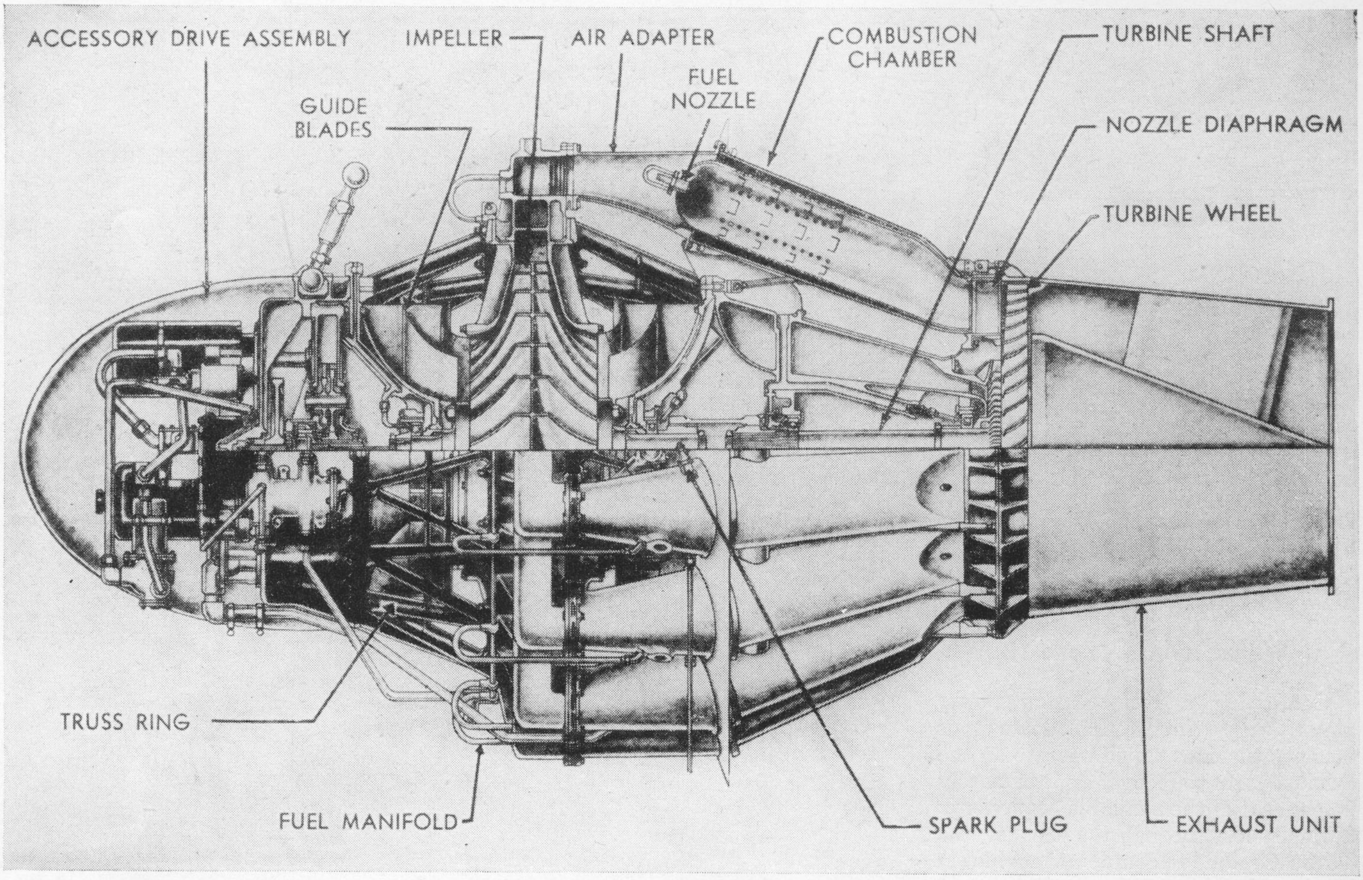


Fig. 1. Cutaway drawing of the GE I-40 turbojet.

balancing, or special fitting. The first three subassemblies may be tested independently, a distinct advantage in production, maintenance, and field service.

The complete assembly is mounted on two horizontal trunnions and a front support. The trunnions project outward between air adapters at the rear air inlet very near to the center of gravity of the gas turbine. The front support can be mounted on either the top or the bottom of the gear casing, depending upon installation.

Fundamental Design Data

Impeller diameter, in	30
Impeller inlet diameter, in	18¼
Impeller hub diameter, in	8
Diffuser throat area, sq in	75
Fuel nozzle size, gph, at 100 psi	40
Turbine nozzle area, sq in	121.3
Turbine pitch diameter, in	22
Turbine nozzle and blade height, in	4
Exhaust pipe diameter, in	21
Jet nozzle diameter, in	19
Max. over-all diameter, in	101½
C.g. (aft of trunnion), in	2

Take-off and military rating of the I-40 is for 15 min at 11,500 rpm. Normal rating is for continuous operation at 11,000 rpm. Idling speed is the minimum continuous operating speed and is for 3,500 rpm.

Average Performance Data

(At 11,500 rpm with standard inlet conditions of 14.7 psi, 59°F, and 0 ram)

Thrust	4,000 lb
Fuel flow	4,740 lb/hr
Specific fuel consumption, lb/hr/lb thrust	1.185
Exhaust temperature	1170°F
Compression ratio	4.126
Compressor discharge temperature	413°F
Combustion pressure drop, psi	3.18
Turbine inlet temperature	1492°F
Air flow, lb/sec	79

Rolls-Royce Derwent Turbojet

The Derwent series of engines are the direct descendants of the original Whittle jet engine and resulted from the work of both the Rover Company and Rolls-Royce.

The Derwent I used the two-sided impeller, 10 combustion chambers, and a single-stage turbine. It developed 2,000-lb thrust at 16,500 rpm and weighed (dry) 850 lb.

The Derwent Marks II and IV each had a 10 per cent increase in thrust over the first model. The Mark III was an experimental model constructed for boundary-layer control studies.

The Derwent V (1) is an 85 per cent scaled-down version of the Nene. It has 9 instead of 10 combustion chambers, as in the Mark I, and its compressor has increased capacity. Pump capacity on the later model is varied by an aneroid to reduce supply at altitude.

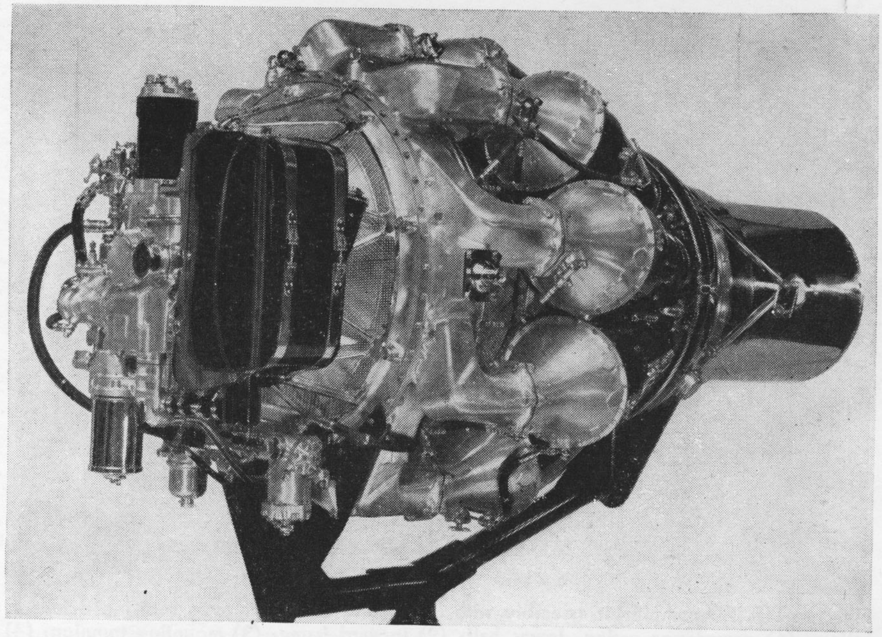


Fig. 1. Powering the Gloster Meteor, the Derwent V gained the world speed record for Great Britain at 616 mph before the record was taken by the United States with the P-80, D-558, and F-86, the latter at a speed just under 670 mph.

Specifications of the Derwent I and V

	Mark I	Mark V
Thrust, lb:		
Static sea level	2,000	3,500
Cruising (15,000 rpm)	1,550	3,500
Rpm, max	16,500	16,500
Weight, lb	850	1,250
Length, in	101.5	83.1
Diameter, in:		
Max	42.5	42
Impeller	20.68	
Turbine	17.38	
Compression ratio	3.9:1	
Throat area, sq in	38	
Jet-pipe temperature, max	690°C	9
Combustion chambers	10	

PART 2. COMPRESSOR DESIGN

General Electric TG-180

The compressor (1) of the TG-180 consists of eleven-bladed disks shrunk on a steel shaft and enclosed in a cast aluminum outer casing. The first 10 disks, forming the first 10 stages, are machined from aluminum forgings. The eleventh disk, the last compressor stage, is a heat-treated steel forging linked directly by a splined fit to the turbine shaft.

The rotor blades, forged and coined to size, are attached to the disk rims with trapezoidal-shaped dovetails. The disks are connected by cylindrical aluminum spacer rings shrunk under the rim shoulders. Each of the eleven disks is secured to an adjoining spacer ring by means of steel pins to carry the driving torque.

The horizontally split compressor casing (stator) is bolted together round the rotor and secured at the ends to the cast aluminum alloy forward frame (2) and mid-frame (3).

Unlike the compressor casing, these frames are not split, and they are the main mounting structures of the unit. The stator blades also are

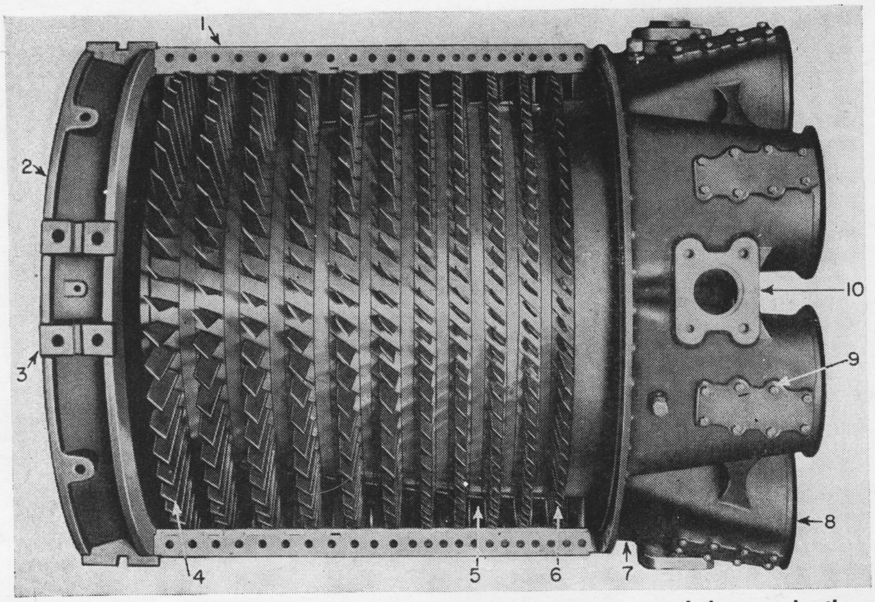


Fig. 1. TG-180 compressor assembly with half of the casing removed showing details as follow: (1) compressor casing, lower half; (2) forward frame; (3) mounting trunnion; (4) first-stage rotor disk; (5) stator blade; (6) eleventh-stage rotor disk; (7) mid-frame; (8) combustion chamber opening; (9) for fuel nozzle opening; (10) main mounting trunnion.

forged and coined to size, are dovetailed into split rings, and in turn assembled into stator halves.

Eleven rows of stationary blades are used, followed by two rows of final straightening vanes. The accessory-drive casing acts also as a bearing support for the front (No. 1) bearing. The mid-frame, at the rear of the compressor casing, supports the main turbine structure or aft frame, and serves as a support for the main thrust (No. 2) bearing. The engine main mounting trunnions are on the horizontal and vertical center lines of the mid-frame located at the c.g. of the unit.

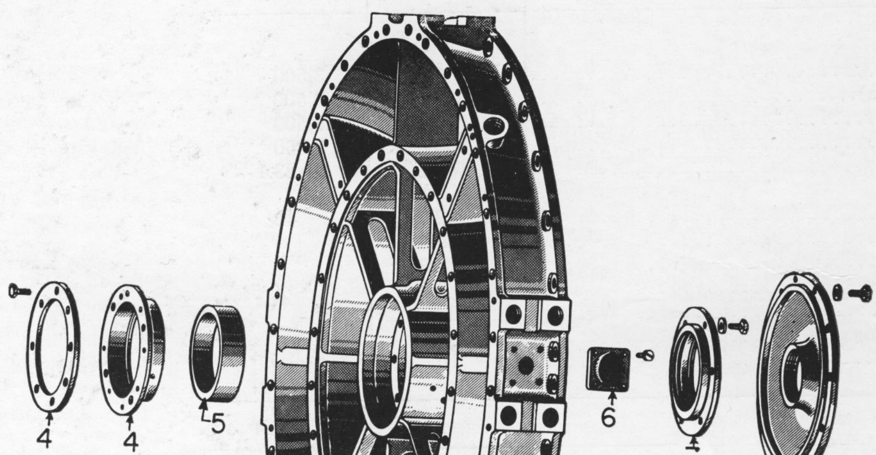


Fig. 2. The forward frame assembly of the TG-180 consists of: (1) lower trunnion; (2) flange for bolting gear casing; (3) bearing thermocouple; (4) No. 1 bearing housing; (5) bearing outer race—inner race is assembled on rotor; (6) screen for air vent openings; (7) bearing oil seals.

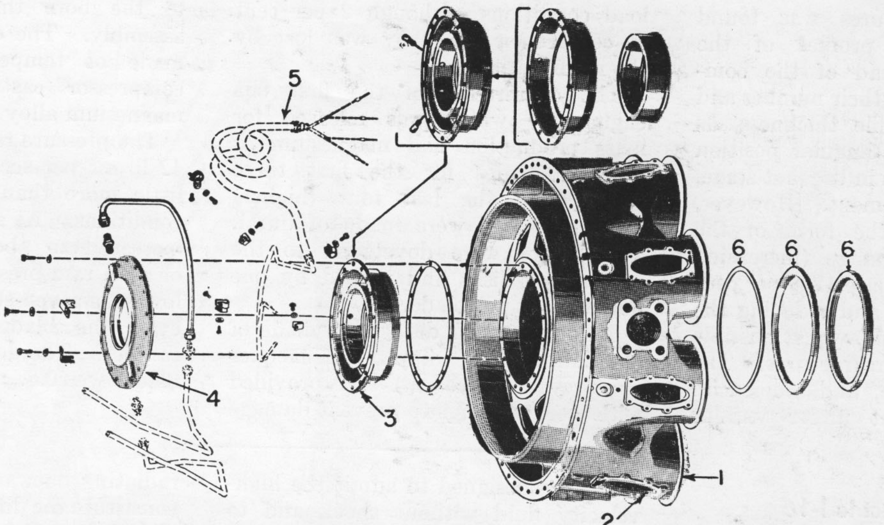


Fig. 3. The TG-180 mid-frame assembly detail shows: (1) combustion chamber opening; (2) fuel nozzle port; (3) No. 2 bearing housing; (4) bearing oil seal; (5) thermocouple; (6) parts for the assembly of No. 2 bearing housing.

BMW-003

In 1939, the Experimental Institute of Aerodynamics at Göttingen developed a model compressor which showed an average efficiency of 80 per cent. The blade velocity of this compressor at the outside diameter was 820 fps, and the axial velocity of air flow was 328 fps.

A compressor similar to this test model was designed for the first BMW experimental units. Blading was arranged in such a way that pressure conversion took place in the rotating blades, while the stator blades served merely for deflection. Profile of the rotating blades was based on a high-speed profile developed at Göttingen for fairly high Mach numbers. When tested on the stand, the compressor showed efficiencies of 80 per cent over a wide range of loads. However, the unit proved to have insufficient capacity for the output specified by the German Air Ministry.

A new design of greater capacity, but with the same diameter, was built by BMW with cooperation of other sources which had a 30 per cent increase in capacity. The number of stages was increased from six to seven, the average air velocity was increased to 460 fps, and the rated rpm of the unit was raised from 9,000 to 9,500. Pressure conversion no longer took place entirely in the rotating blades, but 30 per cent of this pressure rise was accomplished by using guide, or stationary, blades. NACA profiles were used for the rotating blades, whereas arc-shaped profiles were chosen for stationary blades.

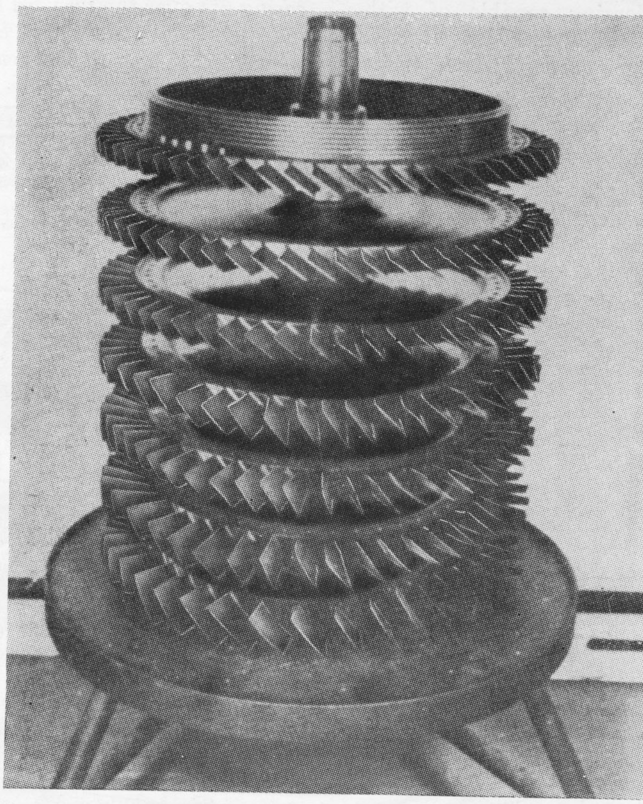


Fig. 1. BMW-003 seven-stage axial-flow compressor assembly, last stage at the top.

Vibration failures occurred during early test runs of the new unit in the first compressor stage after 20 hr or less—usually resulting in complete destruction of the compressor. The

cause of these failures was found in the supporting profiles of the casing mounted ahead of the compressor. Decreasing their number and diminishing the profile thickness, as well as changing the angular position of the rotating blades in the first stage, made some improvement. However, only by changing the form of the blades in the first stage (increasing the thickness of the base 12½ per cent of the profile length and reducing the outer end to 5 per cent) was it possible to eliminate vibration fractures. The unit had longer life, and efficiencies were fairly constant under various load conditions, although 2 per cent in compressor efficiency was lost by the modification.

The compressor of the first 003 engine (1) which was released for mass production had magnesium or electron blades for the first three stages, and the last four (higher) pressure stages were made of dural. The blades were dovetailed to the compressor disks and pinned by one hollow rivet per blade.

The compressor disks were made of aluminum alloy dipped in lacquer (to prevent corrosion) and provided with steel bushings to prevent damage to the bore through frequent disassembly. The compressor shaft was made of tempered steel, and the compressor casting was cast from magnesium alloy.

The pressure ratio at 9,500 rpm and 42 lb air per second mass flow was a little more than 3:1, under no ram conditions. At 560 mph, this ratio increased to about 3.9:1. A static, or zero, ram pressure of 3 is somewhat low for a seven-stage compressor; however, the blades had a fairly flat camber. The design Mach number of blades was 0.8.

General Electric I-16

The GE I-16 (Air Force J-31) turbojet is equipped with a centrifugal air compressor (1) consisting of a double-sided multivaned impeller wheel enclosed in a casing with a diffuser.

The impeller is a heat-treated aluminum forging capable of withstanding the high speed at which it must revolve. The curves of its vanes are designed to admit the high-velocity fluid without shock and to increase the fluid volume by compression with greatest efficiency.

The magnesium-alloy compressor casing consists of front and rear halves. The curved, smoothly machined undersurface of the front casing fits over the forward side of the impeller, and the rear compressor casing is cast with 10 identical channels radiating outwardly. These channels constitute the diffuser. Through them the air is efficiently distributed into the elbows attached to the combustion chambers.

The rotor assembly, a turbine wheel and impeller at opposite ends of a composite shaft mounted on antifriction bearings, is a finely balanced precision component constituting the heart of the engine (2).

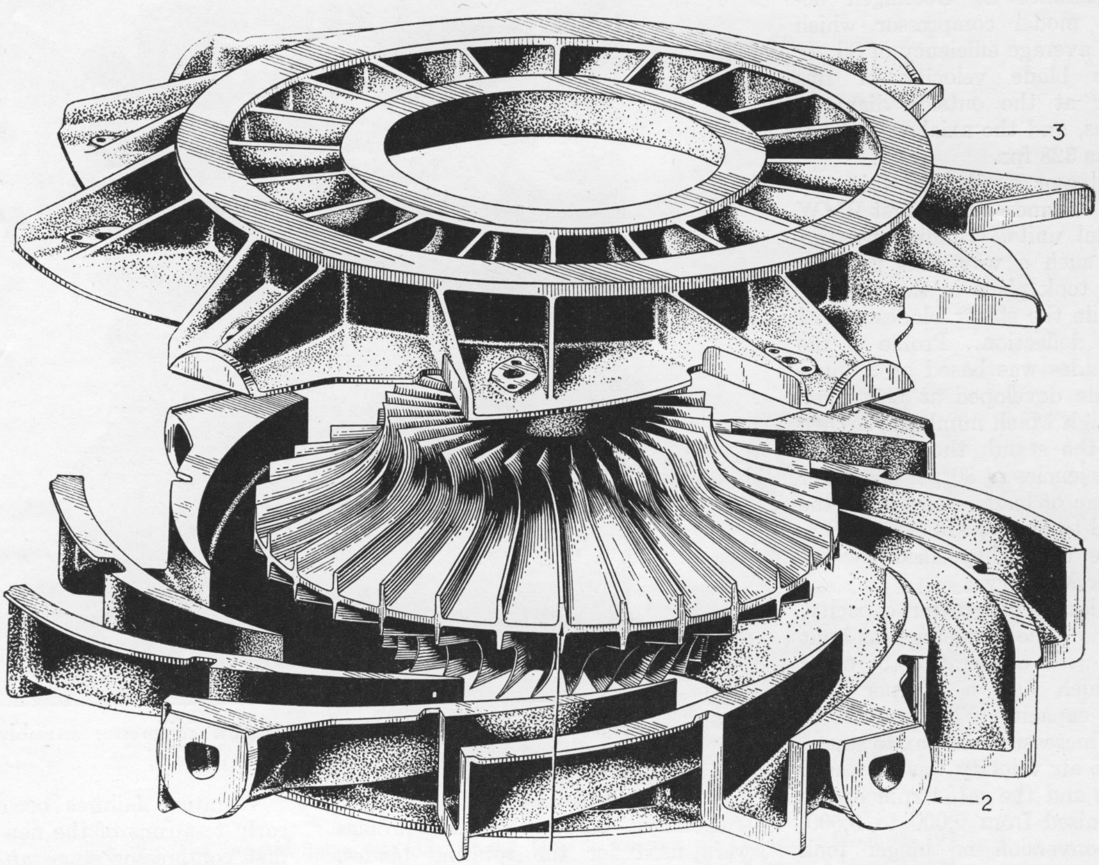


Fig. 1. View of the I-16 centrifugal air compressor showing (1) double-sided impeller; (2) diffuser and lower casing (3) upper casing.

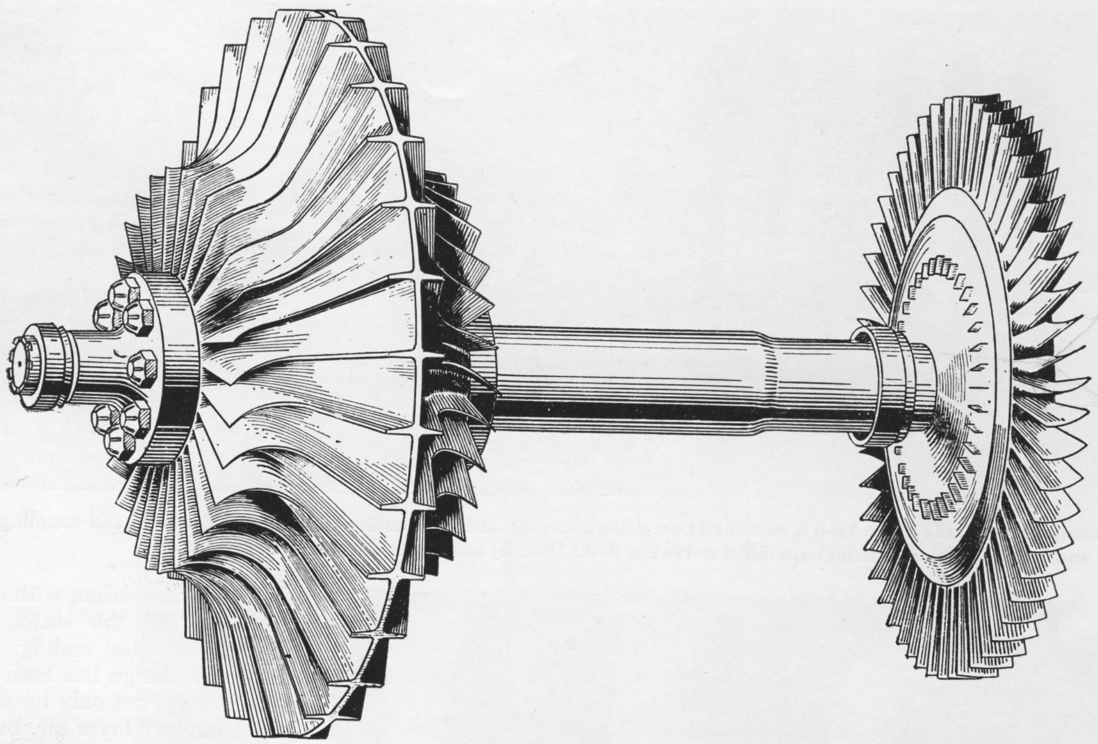


Fig. 2. Engine rotor assembly of the GE I-16. The assembly is composed of a turbine wheel and impeller at opposite ends of a composite shaft.

The wheel shaft is machined with a ball-bearing journal, shoulder for an oil slinger, and a series of splines. After the slinger and bearing are slid down the shaft, a rear shaft, correspondingly splined, is fitted over the entire wheel shaft with a shrink fit.

This composite shaft is then secured with a spring collar, shims, and a shaft lock nut.

The impeller is assembled to the end of the rear shaft with eight studs on one side inserted into drilled holes on the flange of the rear shaft, and eight studs on the other side of the impeller inserted into drilled holes in the flange of the front shaft.

Assembled to the front end of the front shaft are an oil slinger and a ball bearing, secured in place with a lock washer and nut.

Westinghouse 19-B

The Westinghouse 19-B jet-engine compressor is a six-stage type with the spindle (1), including the shaft at the inlet end and coupling flange at the discharge end, machined from a single aluminum forging, each disk having a double-convex cross section. Diameters of the disks range from 9.1 in. at stage 1 to 12.85 in. at the final stage.

The compressor blades (2) are machined steel alloy with bulb-type roots. They are held in place in the milled disk slots by wire locking keys which are turned up into the grooved sides of the blade root. The profiles of the blade are based on a straight-line–circular-arc formula, giving a foil very similar to a laminar flow design. In addition to the aerodynamic considerations, use of this airfoil has been found advantageous in that it is easy, and thus inexpensive, to machine.

The blades in the first compression stage, though having the same foil, have greater chord than do the succeeding stages, all of which are identical except for blade length. Centrifugal stresses in the first stage at the 19-B's maximum of 18,000 rpm reach 30,000 psi.

The cast aluminum compressor casing (3) is constructed in two halves bolted together through axial flanges. In addition to the flanges at either end for attaching to the front bearing support and mounting unit, respectively, the casing is reinforced by a circumferential rib, and two axial ribs spaced at 90 deg from the mating flanges of the halves.

The inside of the casing has six machined grooves, five to take stator blade shroud rings, one for straightener vanes. In most cases the steel stator blades are cast, though some are rolled. The blade ends go through slots in the stainless-steel shroud rings and are gas-welded in place.

Sealing rings, also of stainless steel, are formed by flanges which are welded to both edges of the inner shroud rings. The complete stator blade units are held in place by retaining screws at the base of the mating flanges.

The straightening vane assembly consists of three rows of vanes of

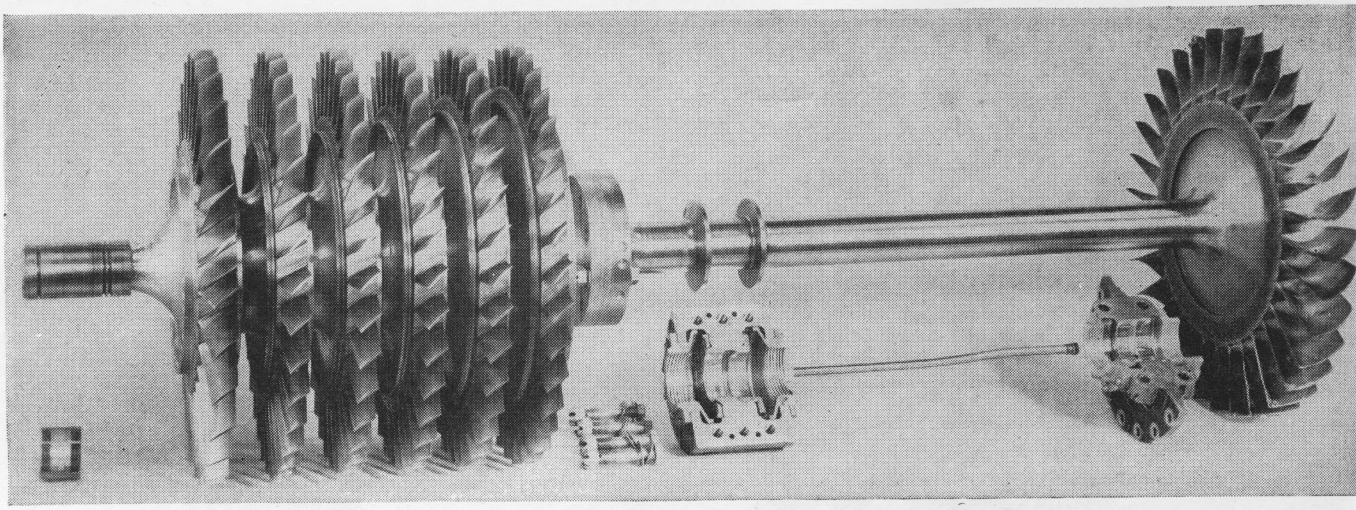


Fig. 1. The compressor spindle of the 19-B is machined from a single forging, as are the turbine disk, shaft, thrust faces, and coupling flange. The front (No. 1) and turbine (No. 3) bearings are radial only; the thrust (No. 2) takes both thrust and radial loads.

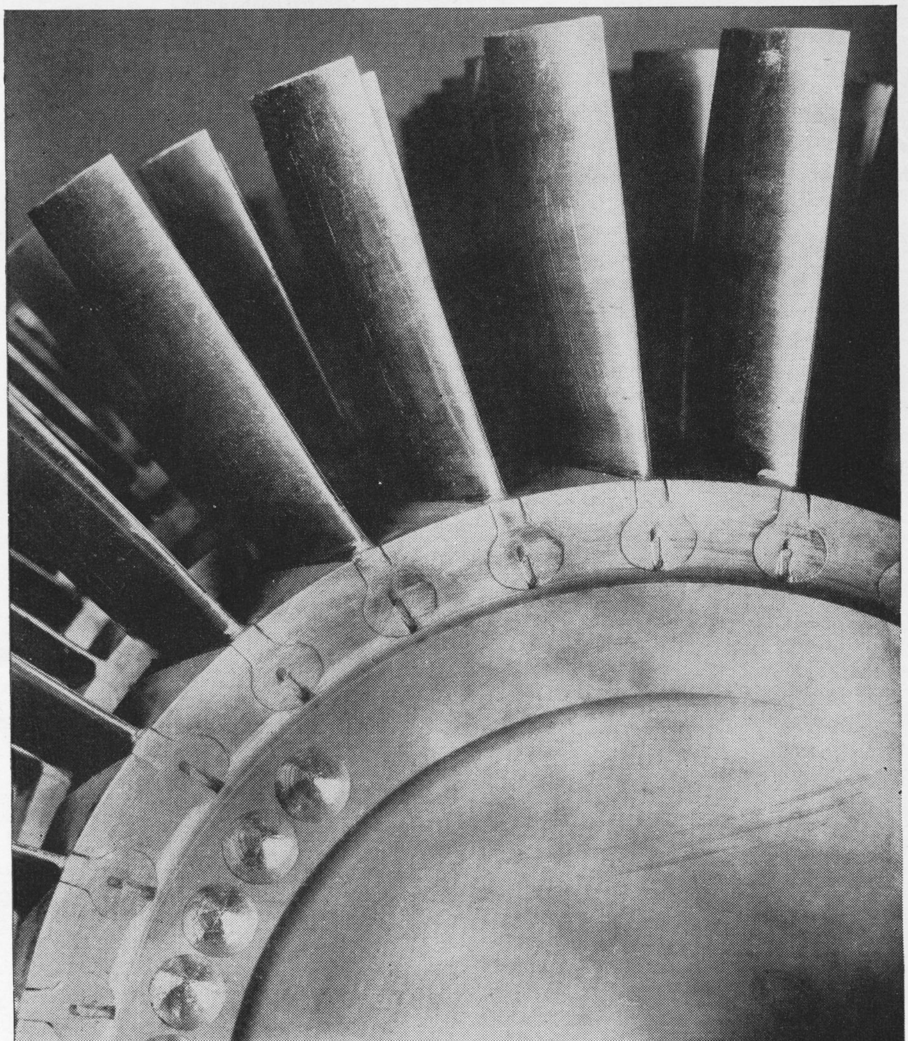


Fig. 2. The compressor blades of the 19-B feature bulb-type roots are held in place in the milled disk by wire locking keys turned up into the grooved sides of the blade root.

NACA 6512 section, with construction like that of the stator assemblies, except for the sealing rings. The three-row design has been found most satisfactory, not only for skimming off the boundary layer air, but for maintaining compressor efficiency and preventing choking.

The pressure rise across each set of rotor and stator blades is equal, the total compression being just over 3:1.

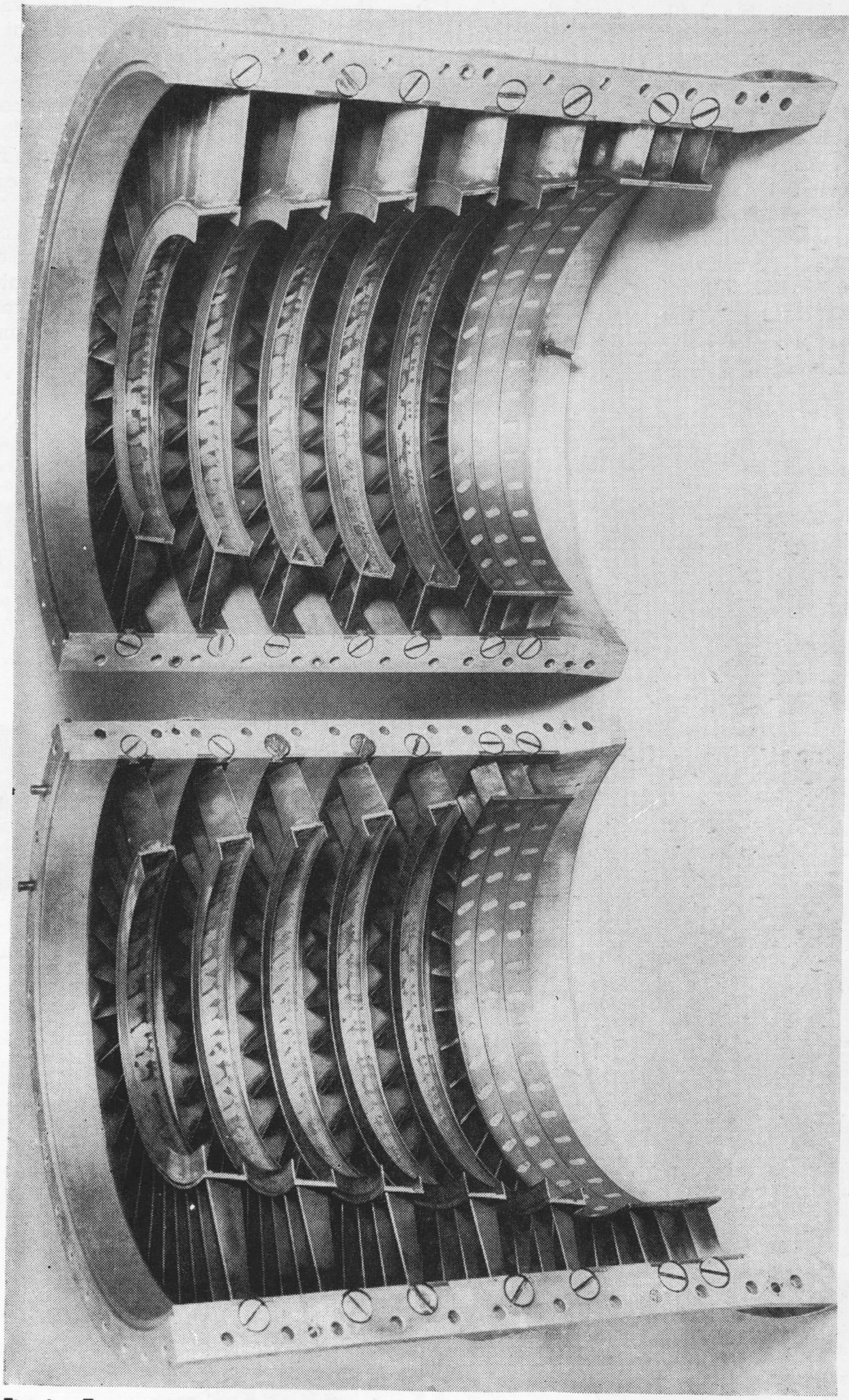


Fig. 3. Top and bottom halves of the Yankee compressor casing with stator blades installed. Both the inner and the outer stator shroud rings are of stainless steel, with blades welded in place in slots. The sealing rings are welded to the shroud rings.

General Electric I-40

The compressor rotor in the I-40 design is comprised of an impeller, a solid aluminum forging with milled blades having inlet sections bent to match the incoming air flow, with stub shafts bolted on each side.

The front shaft is carried by a ball bearing and the rear shaft by a roller bearing (1). Axial clearance is adjusted by a sliding ring which carries the outer race of the ball bearing. These bearings are carried in support casings which are bolted to the flanges of the accessory drive on one end and to the turbine and combustion assembly on the other end.

Truss rings are fastened to these same flanges and span the front and rear inlets, supporting the compressor casings and the diffuser (3). The diffuser is a box-type single casting with the elbows and turning vanes cast integrally, and compressor casings form the side walls of the impeller and support part of the inlet guide vanes (2).

In operation, the air enters the compressor through circumferential inlets on the front and back of the double-sided impeller, the inlets being screened to prevent particles of dirt or stone from entering the air intake. The air is turned into the annulus of the impeller by the guide vanes and a single splitter vane. The design of the inlet does not impart any preswirl to the air as it enters the impeller. Discharge from the impeller enters 14 equally spaced diffuser passages, and at the end of each is a Wirt-type elbow containing four vanes which turn the air 90 deg into the compressor discharge.

Air from the compressor outlets is conducted to the combustion chambers by cast air adapters, which carry the fuel nozzles, domes (end caps) of the combustion chamber, and the spark plugs.

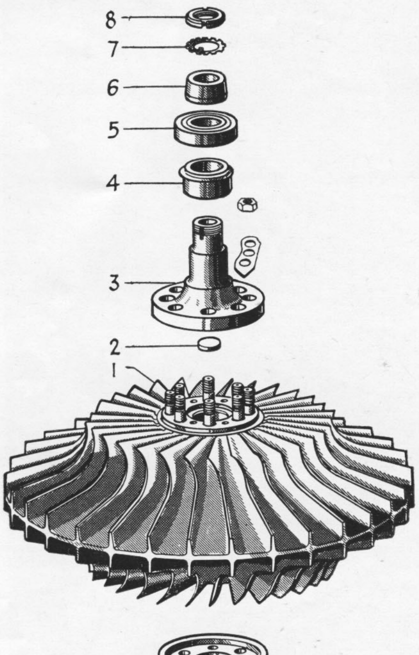


Fig. 1. Details of GE I-40 compressor rotor assembly: (1) impeller; (2) plug; (3) front shaft; (4) oil slinger; (5) ball bearing (6) front bearing spacer; (7) lock washer; (8) lock nut; (9) rear shaft; (10) roller bearing.

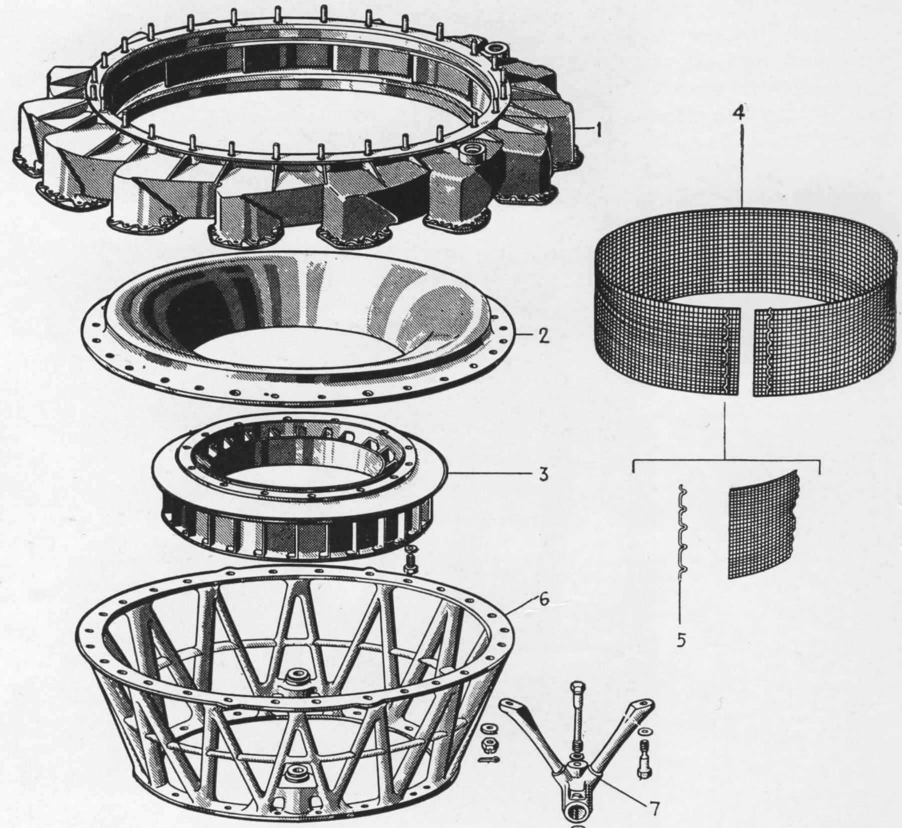


Fig. 2. Rear section of the I-40 turbojet compressor assembly: (1) diffuser; (2) casing; (3) rear guide blades; (4) rear screen; (5) hook; (6) rear truss ring; (7) trunnion support; (8) rear bearing and seal support.

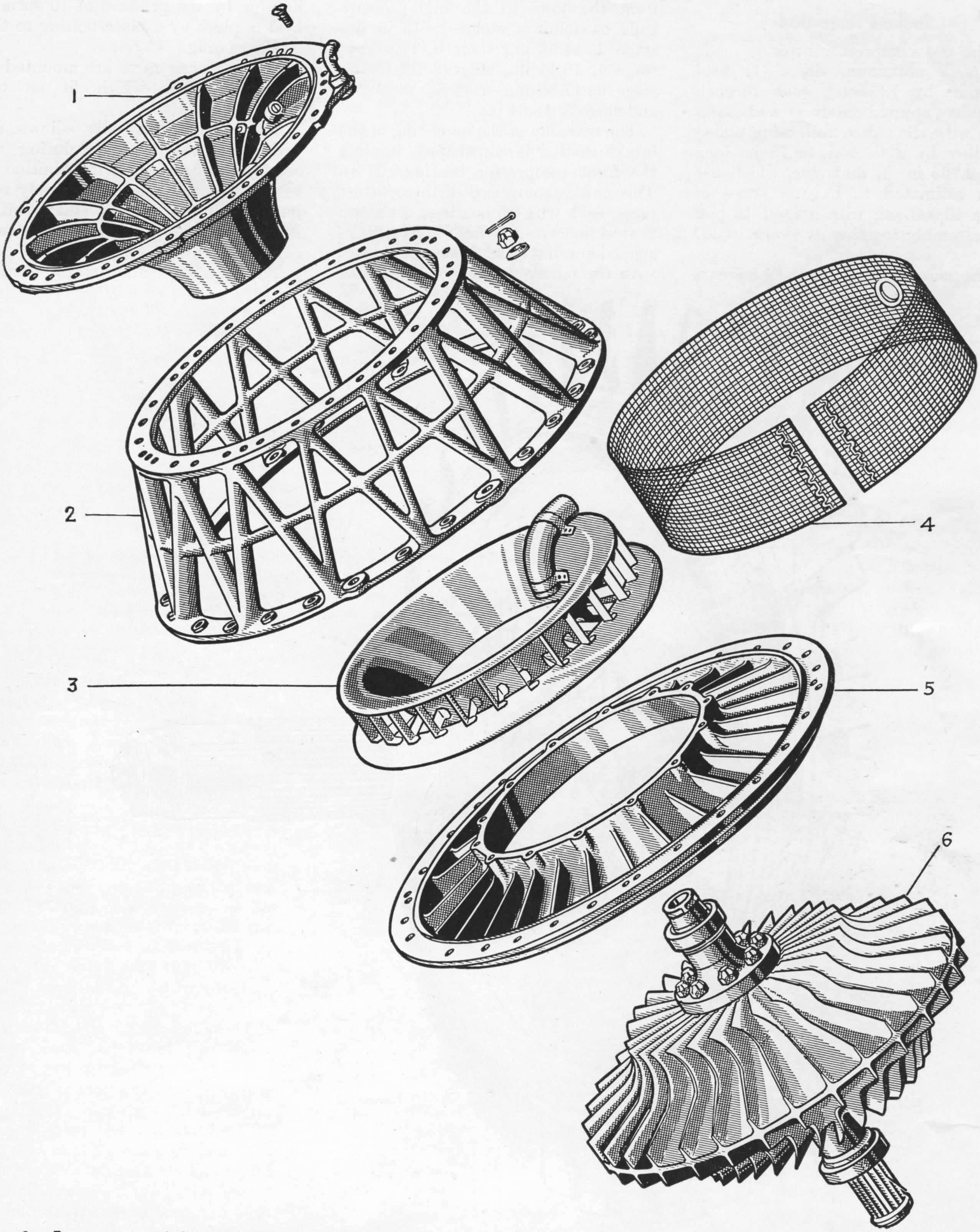


Fig. 3. Front section of the I-40 turbojet compressor assembly: (1) front bearing and seal support; (2) front truss ring; (3) front guide blades; (4) front screen; (5) compressor casing; (6) impeller.

Junkers Jumo-004

The 004 compressor rotor is made up of 8 aluminum disks (1) held together by 12 bolts, each through shoulders approximately at mid-diameter, with the entire unit being pulled together by a tie rod, 38.75 in. long and 0.705 in. in diameter, which has been estimated to have a stress of some 40,000 psi, with a force to pull the assembly together at about 16,000 psi.

The diameters of the disks increase from the low- to the high-pressure ends as follows: stage 1, 13.86 in., stage 2, 14.68 in., stage 3, 15.61 in., stage 4, 16.44 in., stage 5, 17.18 in., stage 6, 17.85 in., stage 7, 18.24 in., and stage 8, 18.34 in.

The rear side of the inner ring of the intake casting is cup-shaped, housing the front compressor bearing (2, 3). This unit is comprised of three thrust races, each with 15 bearings, mounted in steel liners set in a light hemispheric-shaped housing which is kept in contact with the female portion of the intake housing by the pressure of 10 springs held in place by a plate bolting to the intake casting.

Outer bearing races are mounted in separate sleeves which fit on the compressor shaft.

This design not only allows for preloading the bearings during assembly to ensure even distribution of thrust, but the bearing assembly can be left intact during disassembly simply by withdrawing the compressor shaft from the inner sleeve.

The aluminum alloy stator casting

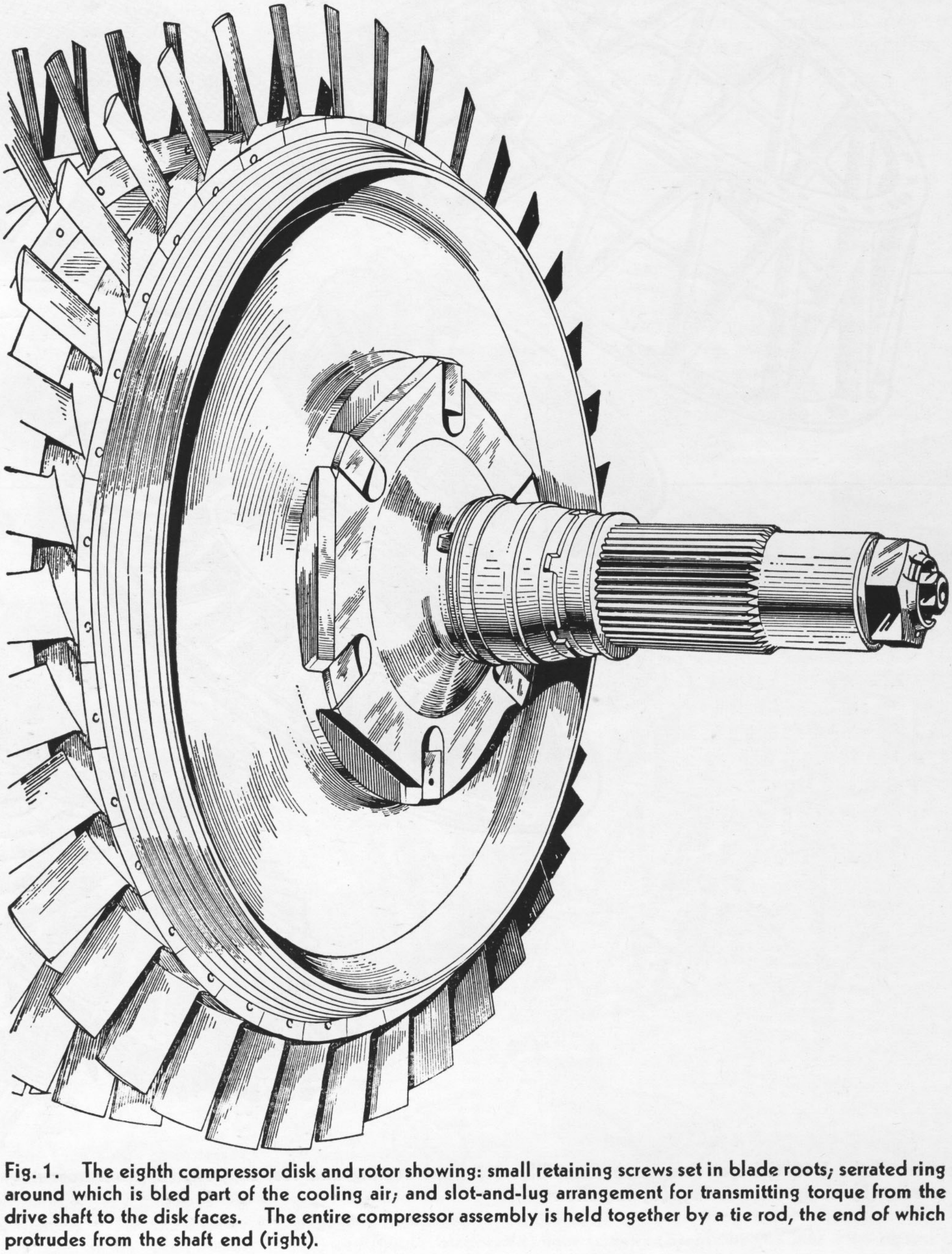


Fig. 1. The eighth compressor disk and rotor showing: small retaining screws set in blade roots; serrated ring around which is bled part of the cooling air; and slot-and-lug arrangement for transmitting torque from the drive shaft to the disk faces. The entire compressor assembly is held together by a tie rod, the end of which protrudes from the shaft end (right).

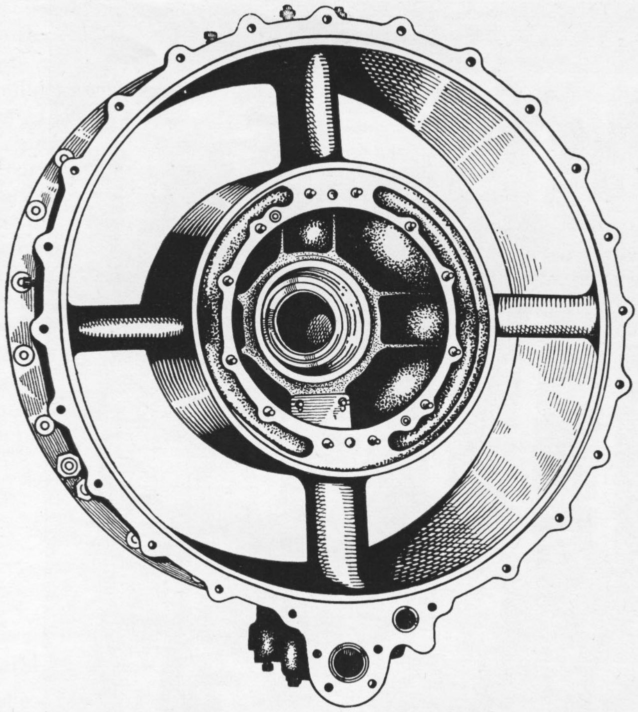


Fig. 2. Intake casting front with oil lines at the bottom. Holes in the outer flange are for attaching the oil and starting-fuel tank assembly. Twelve studs on the inner ring hold the bevel gear assembly from which drives for accessories and oil pumps extend through vertical streamlined fairings.

(4) is next in the fore-and-aft sequence. The top and bottom halves are held together longitudinally by eleven 3/8-in. bolts through flanges on each side, with attachment to the intake casting by twenty-four 3/8-in. bolts through a heavy flange. Running the entire length of the bottom half of the casting are three passages 0.7 in. in diameter, one serving as part of the oil line leading to the rear compressor and turbine bearings, one connecting the oil sumps (located in both intake and main castings), and one serving as part of the oil return line from a scavenge pump set in the rear turbine bearing housing.

Just aft of the fourth compression stage in both halves of the stator casting is a slot, inside of which is a ring with a wedge-shaped leading edge pointing upstream and set to leave a 0.08-in. opening to bleed off air for part of the cooling system.

Consisting of inner and outer shroud rings and stator blades, the stator rings, like the stator casting, are built as subassemblies, then bolted in place and locked by small tabs.

There were, in the 004, varied methods of attaching blades to the shroud rings. On the inlet guide vanes and first two rows, the ends of the blades had been pushed through slots in the shroud rings and brazed in place; the third, sixth, and seventh rows had a weld all around the blade end; the fourth-, fifth-, and eighth-row blade ends had been formed into split cups which were spotwelded to the shroud rings.

The outer shroud rings are channel-shaped with an angle bracket riveted to each end. This bracket, in turn, is bolted to a stud set in the casing just inside the mating flange. The inner shroud rings are flanged along the L.E., with the exception of the seventh row, which is channel-shaped.

Except for the inlet guide vanes and last row of stator blades, which act as straighteners, the stator blades are arranged as impulse blading; *i.e.*, they are set at nearly zero stagger and serve simply as guides to direct air flow into the rotor blades.

To carry the compressor bearings, there is attached to each end rotor disk a steel shaft with an integral disk carrying a round-faced washer. This shaft goes through the disk and is tightened by a nut so that the face of this washer (rounded to facilitate

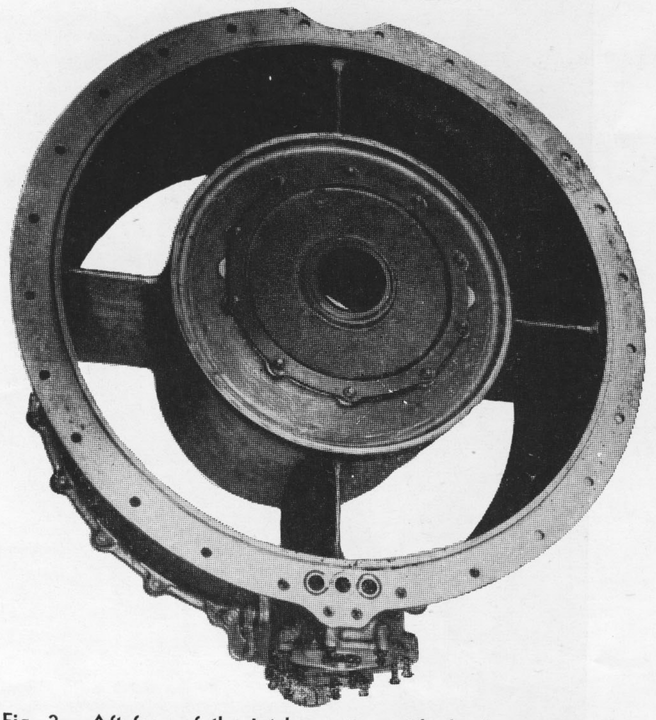


Fig. 3. Aft face of the intake casting with the front compressor bearing held in place by a round plate attached to ten studs. The boltholes in the outer flange are for attachment to the compressor stator casting.

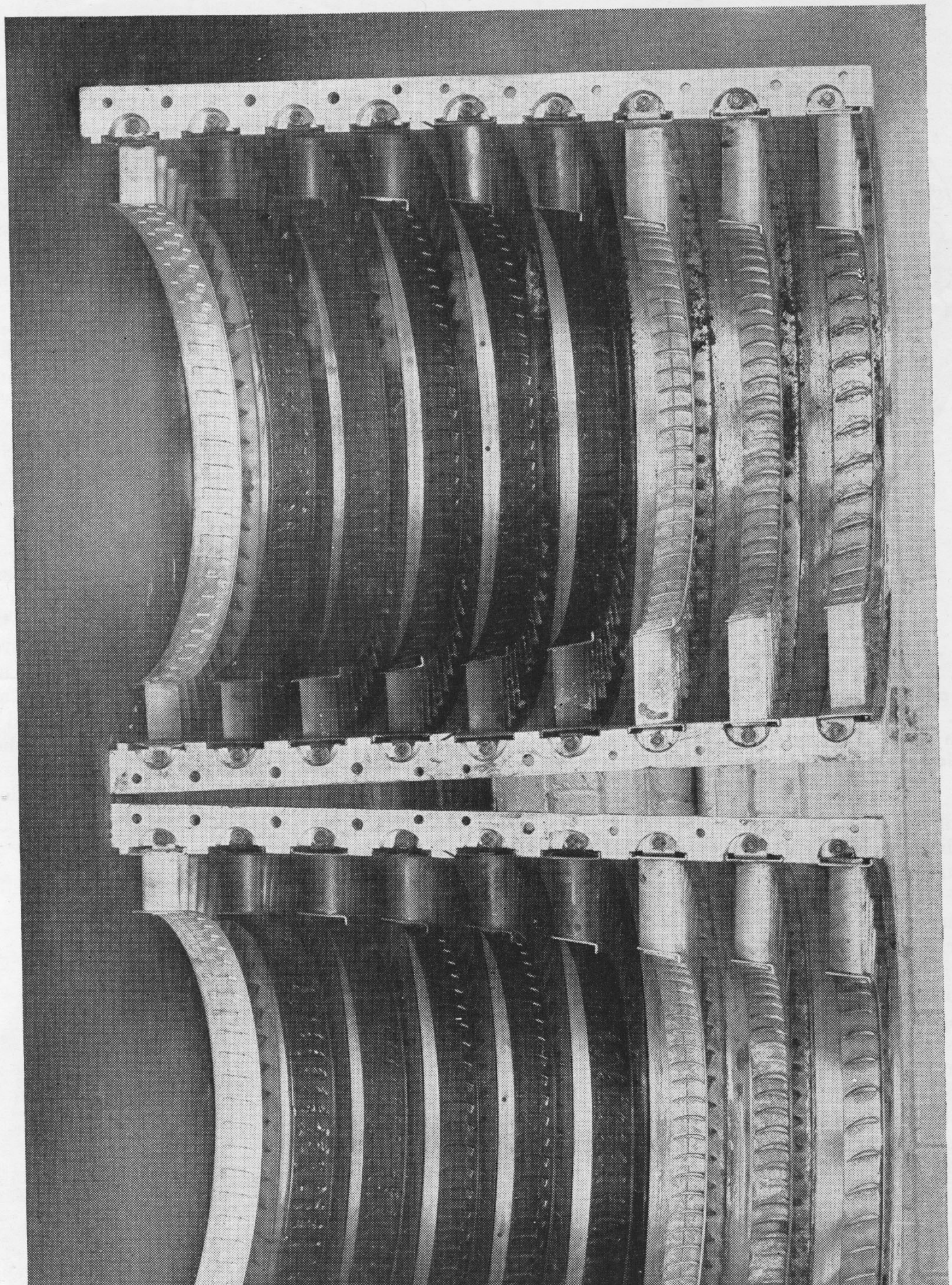


Fig. 4. The stator casting top and bottom halves are bolted together longitudinally with a flange on the front end bolting to intake casing, that on the aft end to the main casting. The light-colored blades are aluminum; the darker are enameled mild steel.

alignment) bears against the disk face. The flange on the rear shaft has six slots around its outer edge, into which fit projections on the rear disk. Thus torque is transmitted from the turbine to the rear compressor disk, and from there on to the other disks by the bolts previously noted as fastening the disks together, the torque being transmitted to the compressor unit around the faces, rather than through a central shaft.

Compressor rotor blades, of which there are 27 in the first two stages, 38 in the rest, are all stamped aluminum with machined roots fitting into pyramid-shaped slots in the rotor disk. Through the aft face of each blade root, directly under the blade trailing edge, is a small screw set longitudinally and extending into the disk.

Tip stagger of the blades is about the same through the first six stages of compression but increases in the last two. The blade chord decreases through the eight stages as follows: 1.95, 1.94, 1.34, 1.33, 1.30, 1.30, 1.24, and 1.21 in.

The blade profiles in the first two stages are very similar (possibly even designed to the same section), while the third stage has a thicker section. Stages 4, 5, and 6 have thinner sections (here, too, possibly the same), with about the same chord as stage 3, while the last two stages, though set at a greater pitch and having a slightly narrower chord, have generally similar camber and profiles.

The clearances between rotor blades and stator casting are 0.103 in. over the first three stages and 0.04 in. over the remaining five. Axial clearances between rotor disks and inner stator shroud rings range from 0.1 to 0.15 in., and axial clearances at the roots between rotor and stator blades are 0.5 and 0.6 in.

PART 3. COMBUSTION SYSTEMS

General Electric TG-180

Each of the eight combustion chambers (1) of the TG-180 consists of an outer chamber fitted with removable liner and fuel nozzle, two of the eight being fitted with ignitor plugs. The chambers are supported by the mid-frame and the aft frame, mounted circumferentially around the latter, and joined to the frames with clamping rings (2).

During combustion, some compressor air is admitted to the liner at the dome, or front cap; the balance of the compressor air is fed to the liner throughout its length via holes and louvers in the shell, thus serving to dilute the very hot gases in the dome region to the desired turbine inlet temperature (about 1500°F) and keep the liner cool. Combustion and dilution processes are complete when the combustion gases reach the turbine nozzle diaphragm.

The combustion chambers are joined near their forward ends by cross-ignition tube connections into which inner crossover tubes are inserted, thus linking the individual liners and spreading combustion from one chamber to the next. At the aft end of each liner a transition piece distributes the hot gases to the turbine nozzle diaphragm. The engine is designed to permit ready replacement of transition pieces and liners without engine disassembly.

The aft frame, bolted to the mid-frame, provides support for the entire turbine and exhaust assemblies, and also embodies the support plate to which the combustion chambers are connected. A fabricated assembly of stainless steel, it utilizes internal longitudinal hat-section stiffeners.

A fire-wall baffle, immediately aft of the mid-frame, isolates the front part of the engine with its fuel and lubrication piping from hot turbine

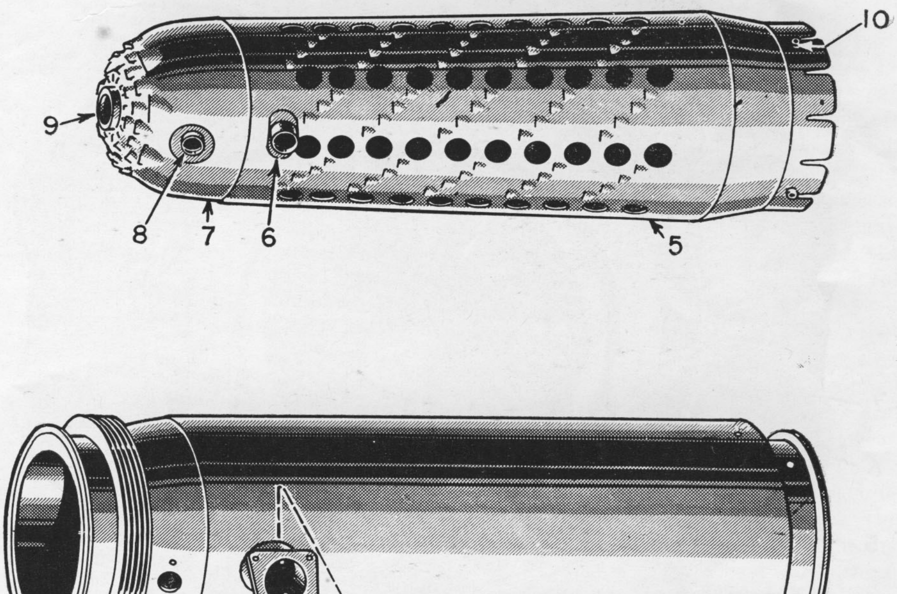


Fig. 1. TG-180 combustion chamber drawing showing typical construction details: (1) outer chamber; (2) outer cross-ignition tube assembly; (3) ignitor plug flange; (4) expansion bellows, internal on most models; (5) combustion liner; (6) ferrule for cross-ignition tube; (7) liner dome; (8) ignitor plug ferrule; (9) fuel nozzle ferrule; (10) liner support boss.

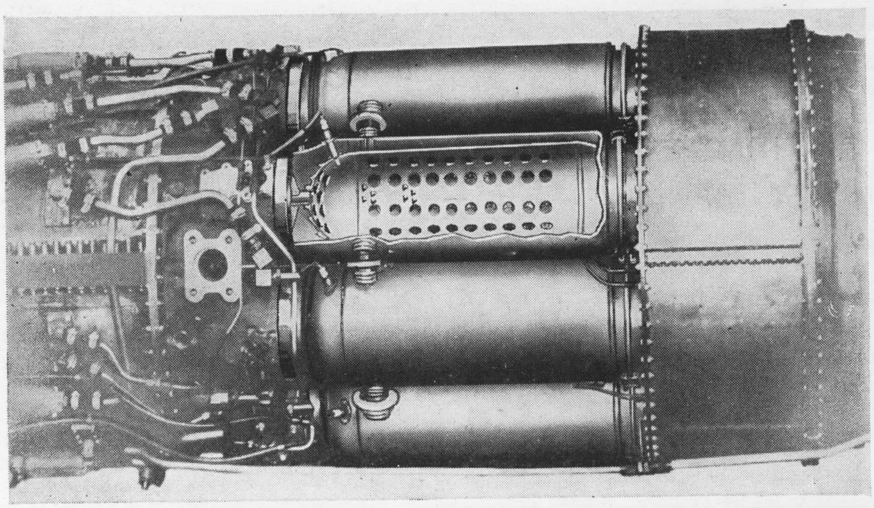


Fig. 2. Combustion chamber installation details show clamp rings visible at the extremities of the separate units. Transition liners (not seen) leading from the chambers to the nozzle diaphragm are housed between bolted circumferential members seen at the right.

parts at the aft end. While no engine cooling is required aft of the firewall, ventilation or insulation normally is required to protect the aircraft structure from radiated heat. The fire-wall baffle is fabricated stainless steel or an integral part of the engine mid-frame casting, depending on the engine model.

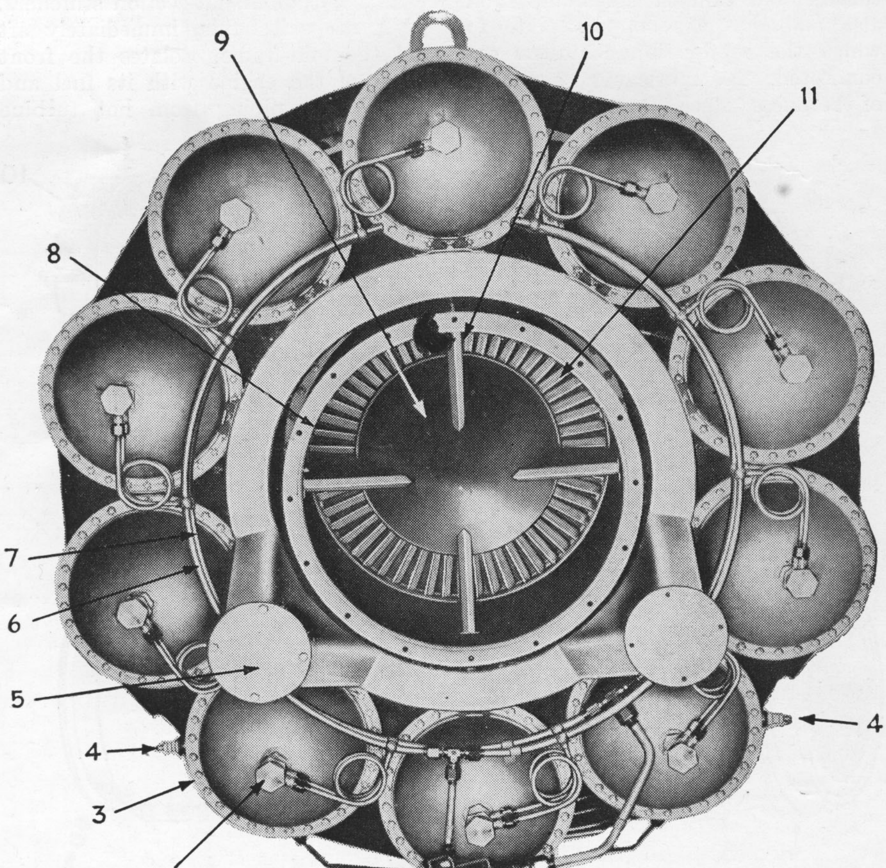


Fig. 1. Rear view of I-16 turbojet unit showing (1) duplex meter valve; (2) fuel nozzle; (3) combustion chamber; (4) spark plug; (5) cooling air manifold; (6) and (7) rear and front fuel manifolds; (8) exhaust cone; (9) inner exhaust cone; (10) strut; (11) turbine wheel.

General Electric I-16

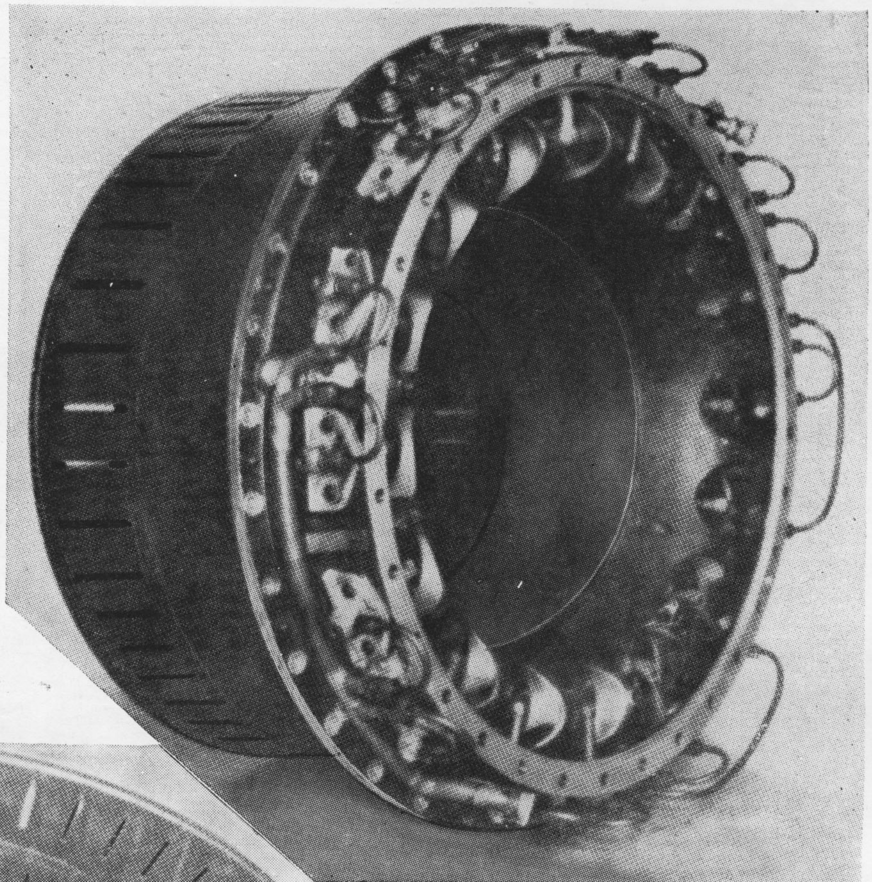
The I-16 turbojet has 10 counterflow combustion chambers (1) each consisting of an outer casing of stabilized 18-8 stainless steel and an inner removable liner of Inconel. The outer chambers are linked by short connecting pipes into which liner interconnectors of the same metal are inserted to link the liners. Each combustion chamber is sealed at the end by a domed cover containing a burner nozzle for the introduction of fuel. A curved elbow leads from each combustion chamber to the turbine nozzle diaphragm.

BMW-003

As a result of continued systematic development efforts, BMW was able to design and construct a combustion chamber (1) which had a low pressure loss, yet had a sufficient margin to ensure stable combustion.

After leaving the compressor, the air is divided into two streams: primary and secondary. The primary air stream passes through the burner and provides the oxygen to burn the injected fuel. By means of special mixing fin elements, secondary air is introduced into the hot gas stream at a specified point downstream from the burners. This secondary air serves to lower the temperature of the gas sufficiently to meet the turbine inlet temperature requirements and also to maintain uniform temperature at the end of the combustion chamber, thus eliminating hot spots (2).

From a structural viewpoint, the ratio of primary to secondary air is determined essentially by the free passage areas at the burner end and at the mixing fins. This ratio can be adjusted by varying the appropriate passage areas until the desired result is obtained. With this combustion chamber configuration, it proved possible to reduce the ratio between maximum and mean temperature of the hot gas to 1.2, as against 1.8 to 2.0 for earlier designs.



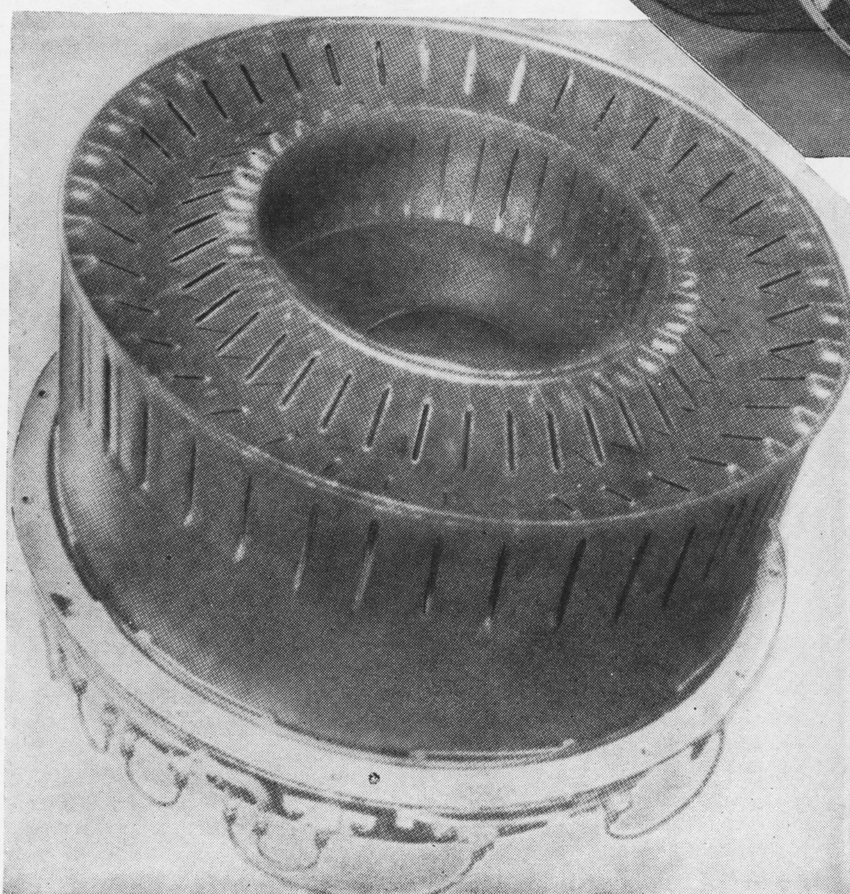


Fig. 1. Three-quarter views, front and rear, of the BMW-003 combustion chamber. The rear view shows the fuel manifold and nozzles; the front view illustrates the inner liner.

The annular combustion chamber incorporates 16 fuel-injection nozzles, each having an eddy-producing conical element around the nozzle tip, and 80 mixing fins divided evenly between the inner and outer rings (3).

The forward section of the combustion chamber, which carries the fuel nozzles and conical eddy-producing elements, is a sandcast aluminum alloy piece. Liners for the chamber are 1010 steel and are protected against fusion by an aluminum lacquer burned in at a temperature of 400°C.

The mixing fins were in a much hotter zone and were built of a better heat-resistant alloy, known as "Sicromal," possessing a high chromium content and containing silicon and aluminum to improve its heat-resisting properties.

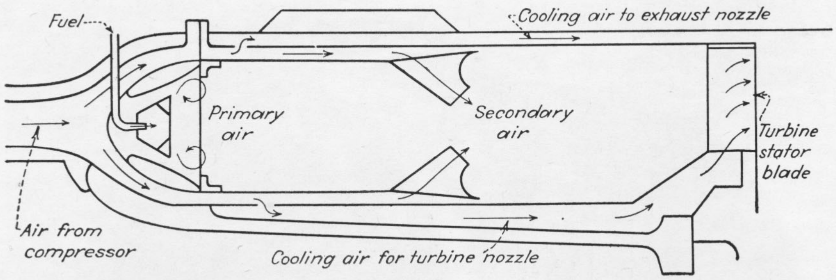


Fig. 2. The paths of fuel flow and air are illustrated in a sectional diagram of BMW-003 annular combustion chamber.

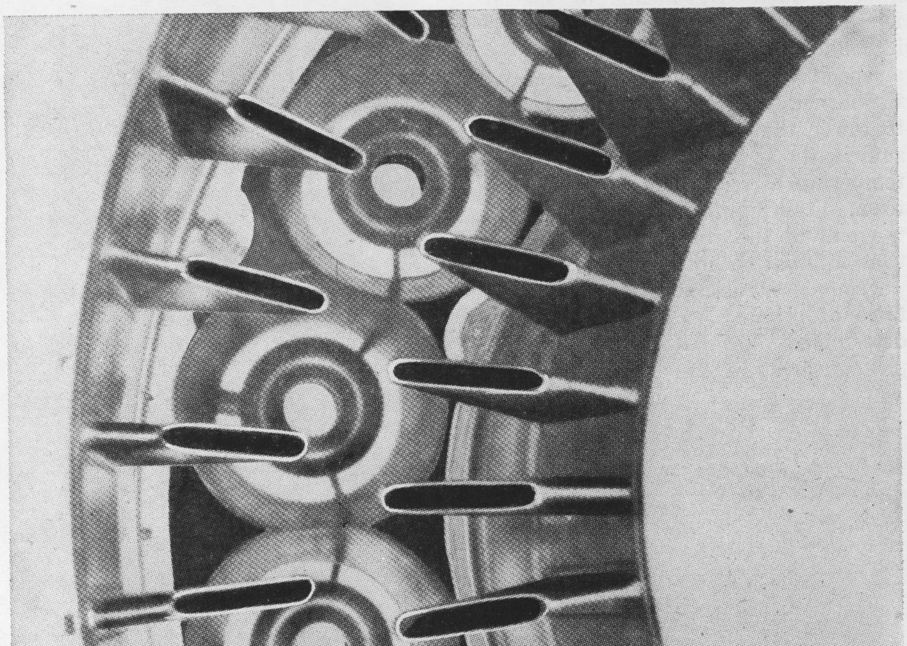


Fig. 3. Close-up of the combustion chamber sandwich mixers. Conical eddy producers are in the background.

Westinghouse 19-B

The annular combustion chamber of the 19-B, a built-up welded cylinder comprised largely of normalized stainless steel, is flanged to the fuel manifold-bearing assembly. The combustion chamber includes a perforated conical burner ring so designed that the turbulence created gives complete combustion at the high velocities developed by the Yankee. One feature is the direction of a layer of cooling air along the inner surface of the casing shell so that the temperatures of the casing do not exceed 400°F.

The backbone of the 19-B is the fuel manifold and thrust (No. 2) bearing support (1), a built-up stainless-steel unit comprising three concentric rings tied together by eight hollow streamlined struts.

The outer single-walled ring, 5 in. long, has two welded flanges, that on the intake end supporting the compressor casing, while that on the exhaust supports the combustion chamber.

Welded to the front flange of this outer ring are the four engine mount lugs, $2\frac{13}{16}$ in. aft of c.g. When installation permits the use of all four lugs, the engine mount system will withstand all flight loads from the power plant itself, but not those imposed by deflections of the air frame. A preferable mounting system calls for the use of the two top lugs and of the auxiliary compressor flange for stabilizing in a vertical plane.

The middle of the three rings serves to split the air to streamline its flow into the combustion chamber as well as to function as the fuel manifold ring and support for the burner basket. The 24 nozzles, of 9.5- to 12.5-gpm capacity, are installed on the machined aft face of this ring. In some installations the spray is set at a 45-deg angle; in most others at 80 deg. In early installations each of the nozzles was protected by an 80-mesh screen strainer, but this was later changed to 120 mesh.

The inner ring, converging toward the rear, extends 6 in. into the combustion chamber and, for the most part, is single-walled. The thrust bearing support is welded to the inner ring, forming a double wall at the support. At the forward end of the ring there is an axial flange, to the inside of which are welded 18 anchor nuts for securing the inner connecting

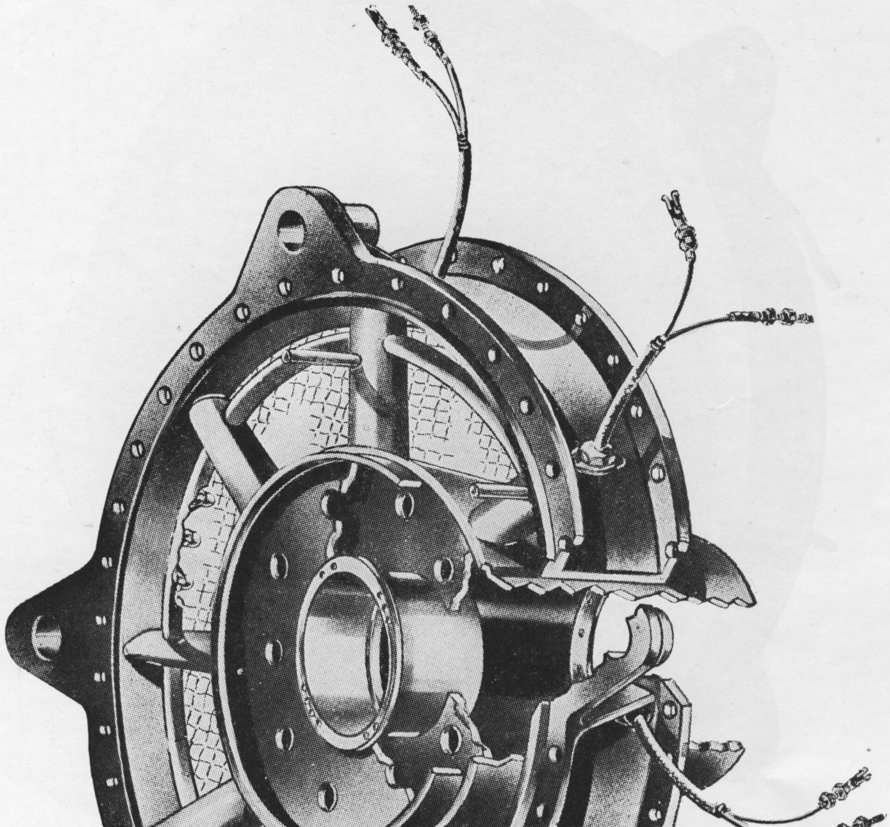


Fig. 1. The backbone of the Yankee 19-B is the built-up fuel manifold and thrust bearing support, shown in R. W. Hibbs sketch. On the outer single-walled ring are four mounting lugs which can support full engine loads. The smaller ring inside serves both to split and streamline the air entering the combustion chamber, and to support 24 fuel nozzles. The inner ring contains thrust bearing housing. Seven of the eight faired hollow struts house passages for thermocouples and oil lines.

cylinder. At the rear end of the ring is a flange drilled to take 16 tap bolts for securing the rear (No. 3) bearing support.

Extending between the inner and outer rings along the aft face is a 6 by 6 per sq in. mesh, 53 per cent open area screen which creates turbulence and mixing of the air flow to the combustion chamber (2).

Seven of the eight struts connecting the rings provide passages as follows, reading clockwise from the intake end:

Struts 1, 2, and 8—leading edge drilled to mount a thermocouple for measuring compressor outlet temperature.

Strut 3—passages for leads of rear bearing oil-outlet thermocouple.

Strut 4—inlet-oil line to thrust (No. 2) and rear (No. 3) bearings.

Strut 5—two oil-return lines from bearings 2 and 3.

Strut 6—passage providing for leads of thrust bearing outlet thermocouple.

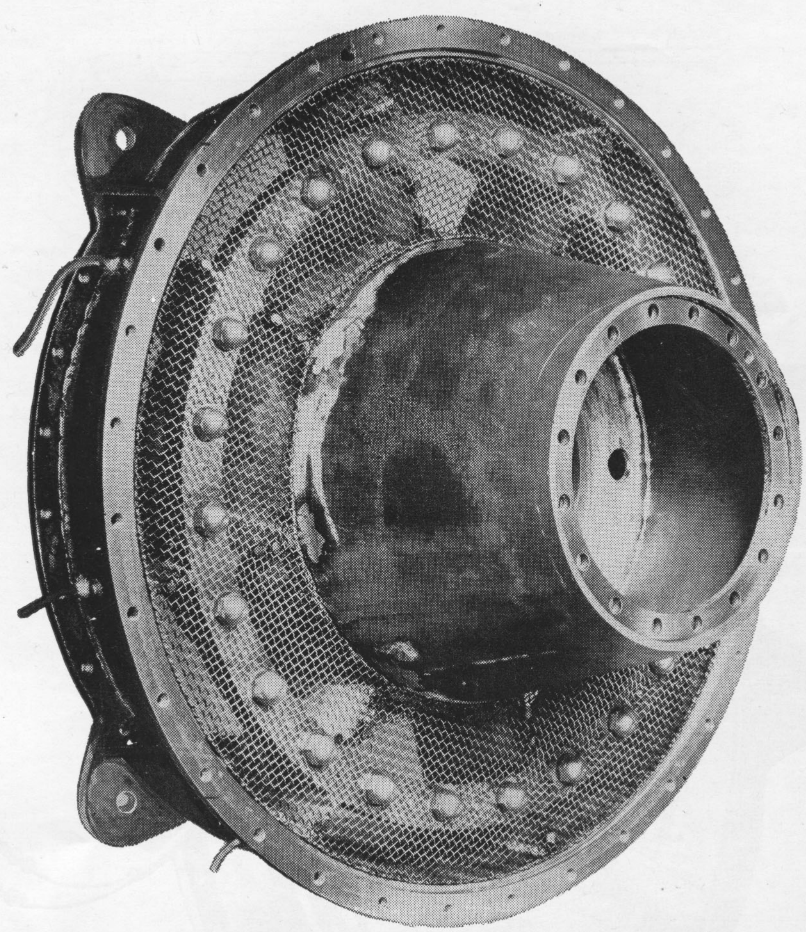


Fig. 2. A rear view of the fuel manifold support showing the screen which creates turbulance as air enters the combustion chamber, and giving the location of fuel nozzles, seen with protecting caps in place.

Junkers Jumo-004

Each of the six 004 combustion chambers (1) is composed of three major components (4) having a combined weight of 19 lb. First, there is the mild-steel outer casing, of $5\frac{3}{4}$ in. in diameter at the entering end, flaring out to $8\frac{5}{8}$ in. and having a length of $20\frac{5}{8}$ in.

The front end has a collar with a rubber sealing ring which is pushed up against the aft face of the main casting to take care of air leakage and to compensate for the difference in casting and combustion chamber expansion.

The flame tube, the second component, fits into the front end of this casing and has two main components: the entry section and the stub pipe assembly. The forepart of the entry section flares out somewhat as does the outer casing, and at the front end has a six-blade swirler made of 22-gauge mild steel with black enamel coating.

The stub pipe assembly is made up of 10 flame chutes welded to a ring (welded by brackets to the rear end of the flame tube) and to a 4-in. dished baffle plate at the rear. To help direct air into the chutes, $\frac{1}{2}$-in. circular baffle plates are riveted to the forward ring. This unit is of mild steel with an aluminized finish.

The third major component of the combustion chamber is a 20-gauge aluminized steel liner, 11 in. long, having a corrugated outer skin which permits cooling air to flow inside the outer casing. This liner fits into the aft end of the casing. The aft ends of the combustion chambers are bolted around flanges to a ring of six rings which fits over the rear end of the main casting.

Ignition interconnectors between chambers are only $\frac{15}{32}$ in. in diameter, and starting plugs are provided in three of the six chambers. These elements, like the fuel plugs, are enclosed in streamlined fairings.

Surrounding the combustion chambers is a 16-gauge mild-steel, double-skinned casing (3) having flanges welded at both ends—that at the front attaching by studs to the main casting; that at the rear attaching to the turbine inlet duct outer flange and the exhaust casing flange. Besides the boltholes in the front flange, there are 24 of similar size, 12 leading to six ducts of 22-gauge steel which carry the air bled from the fourth compressor stage through the combustion chamber casing, and 12 directing air round the combustion chambers. These ducts also help stiffen the skin, as it takes the weight of the entire exhaust system.

Six large handholes are cut in the casing just behind the flange. These

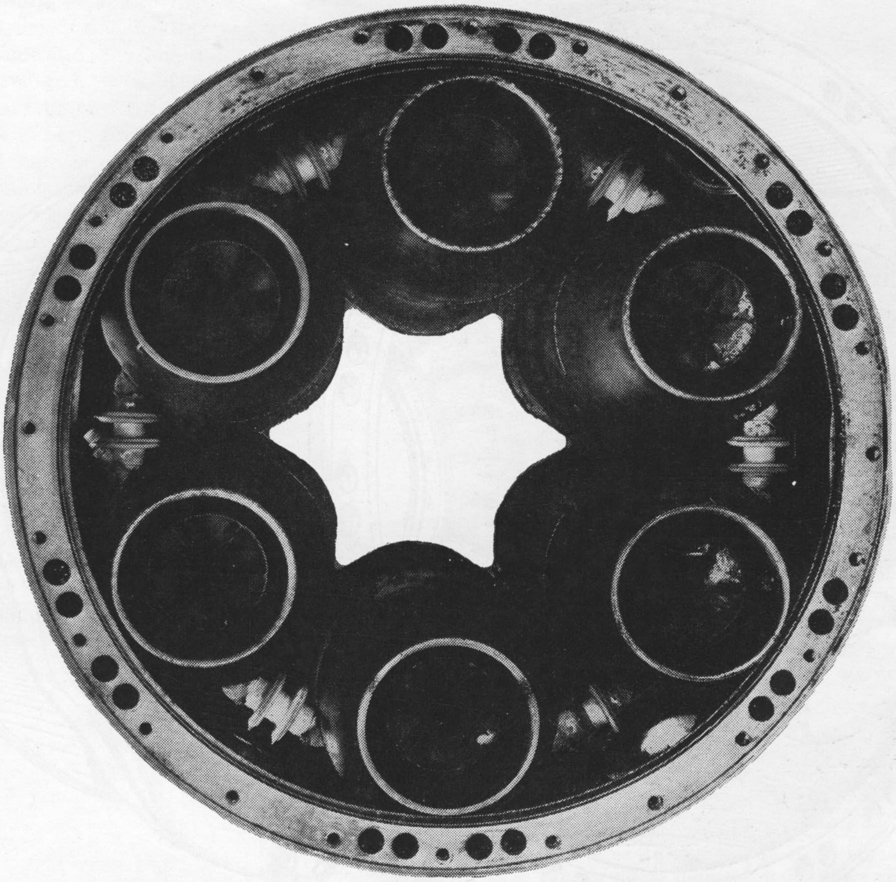


Fig. 1. Front view of a combustion chamber casing with combustion chambers and ignition interconnectors and plugs in place. Every other chamber has an ignition plug.

give access for making minor adjustments to burners and the three ignition plugs.

A little more than halfway aft around the combustion chamber casing is a heavy collar comprised of two channel-shaped members; inside the casing at this ring are six tie rods, connecting it to the main casting (2). Any one of these six units can serve as the aft-engine pickup points; in the case of the Me-262, it is the top one.

Ducting from the combustion chambers to the turbine nozzle changes the air passage from the six circles to an annular shape (5). Attached to the combustion chambers by bolts, this 19-gauge aluminized mild-steel unit is made in two parts, the rear of which is welded to a heavy flange. Studded to this flange from the inner shroud ring of the turbine nozzle assembly are two mild-steel diaphragm plates. These, in turn, are studded to the rear end of the main casting, and so support the inlet ducting and turbine nozzle ring.

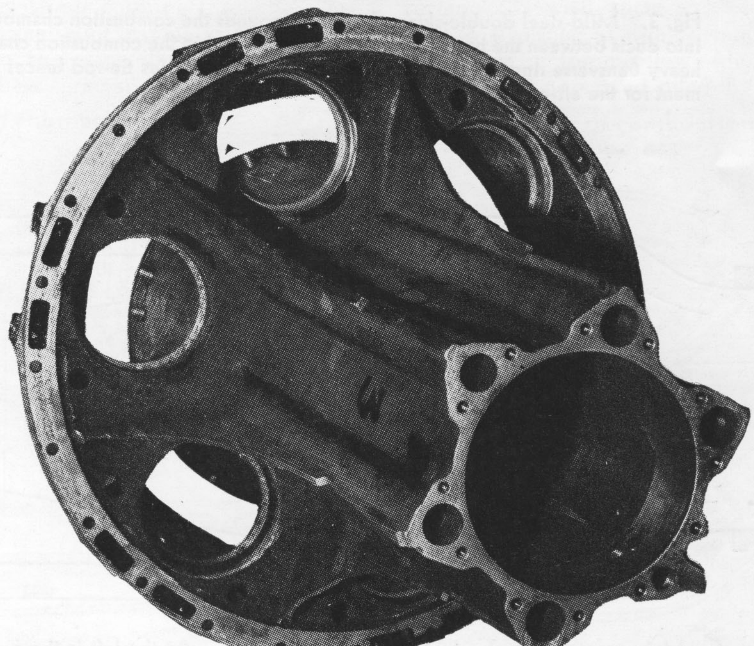


Fig. 2. Main casting rear view showing rectangular cooling air passages and six combustion chamber inlets. The five large cored passages in the base of the ribs are cooling air passages; the smaller is the oil line. The aft turbine bearing fits in the rear end of this casting.

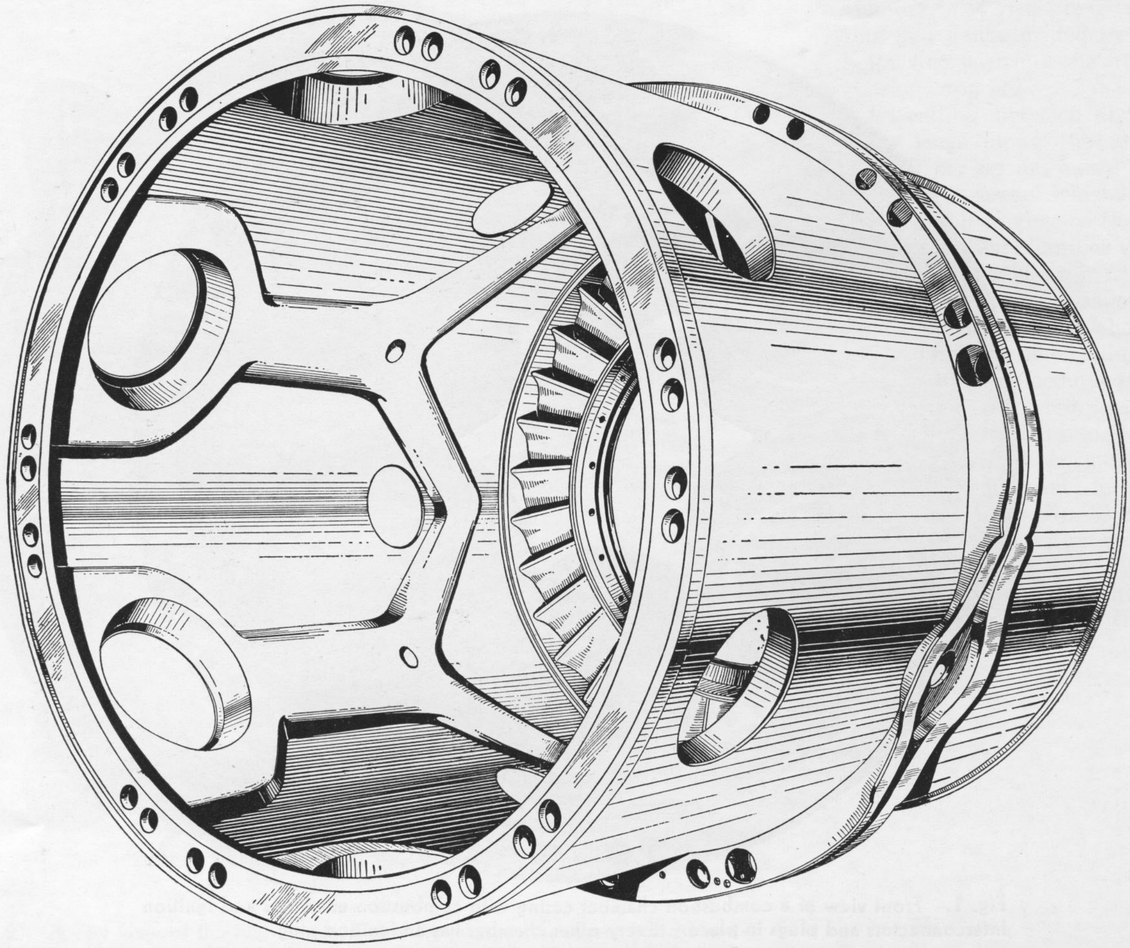


Fig. 3. Mild-steel double-skinned casing surrounds the combustion chambers. Holes in the front ring carry cooling air into ducts between the two skins. Access holes lead to the combustion chamber ignition plugs and interconnectors. A heavy transverse ring around the outside of the casing carries tie-rod braces into the main casting and serves as an attachment for the aft-engine pickup point.

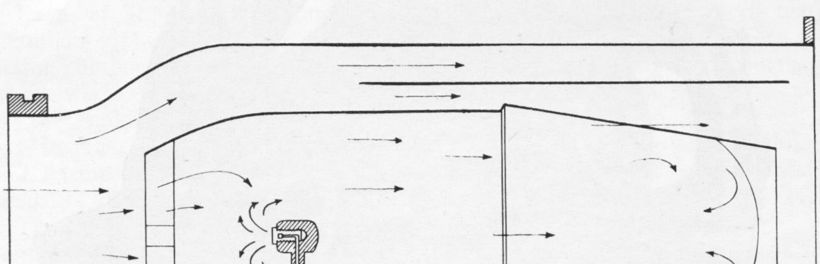


Fig. 4. Main components of a 004 combustion chamber. At the left is the outer casing, made of mild steel; in the center is a flame tube, showing a swirler at the front, fuel nozzle, ignition plug connection (on the side), and stub pipe assembly; at the right is an aluminized steel liner. Corrugations carry cooling air along inside the casing.

On the rear of the outer turbine inlet ducting, a light flange mates with a flange on the rear of the combustion chamber casing. Thus the turbine inlet ducting, to which the combustion chambers are attached, is supported partly by the main casting, partly by the diaphragms, and partly by the skin.

As a result of the final design, it is a major operation to get at the combustion chambers. First, the variable-area nozzle operating shaft must be removed so that the complete exhaust assembly can be taken off. Then, unless special equipment is available, the engine must be placed upright on the turbine disk and burner pipes and the ignition leads disconnected from the combustion chambers. Then the compressor casing–main casting joint can be broken and the whole front end of the engine lifted off.

Next, the rear compressor bearing assembly, torque tube, and locking ring can be removed and the main casting assembly removed, when the nut on the front end of the turbine shaft is unscrewed. The rear diaphragm plate then can be removed and the turbine inlet ducting and combustion chamber assembly lifted off. Then the front diaphragm plate is removed and the turbine inlet ducting, with the combustion chamber assembly, lifted out of the casing. At this point the individual combustion chambers can be taken out.

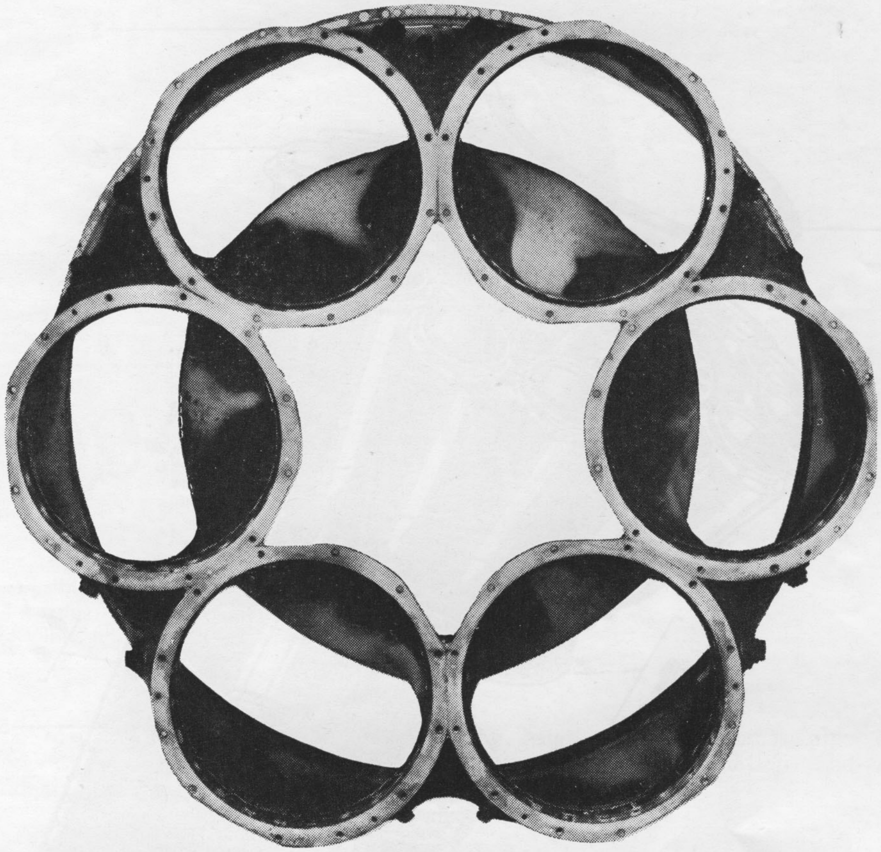


Fig. 5. Turbine nozzle inlet ducting which changes the air passage from the individual combustion chamber circles to an annular shape before entering the nozzle.

General Electric I-40

The 14 combustion chambers of the GE I-40 design are of the through-flow type, with air entering from the compressor end and leaving at the turbine end in the same direction (1). The chambers are arranged around the turbine (2) with their axes conical, joining together at the turbine inlet to provide an annular flow of hot gas.

Combustion is controlled by holes

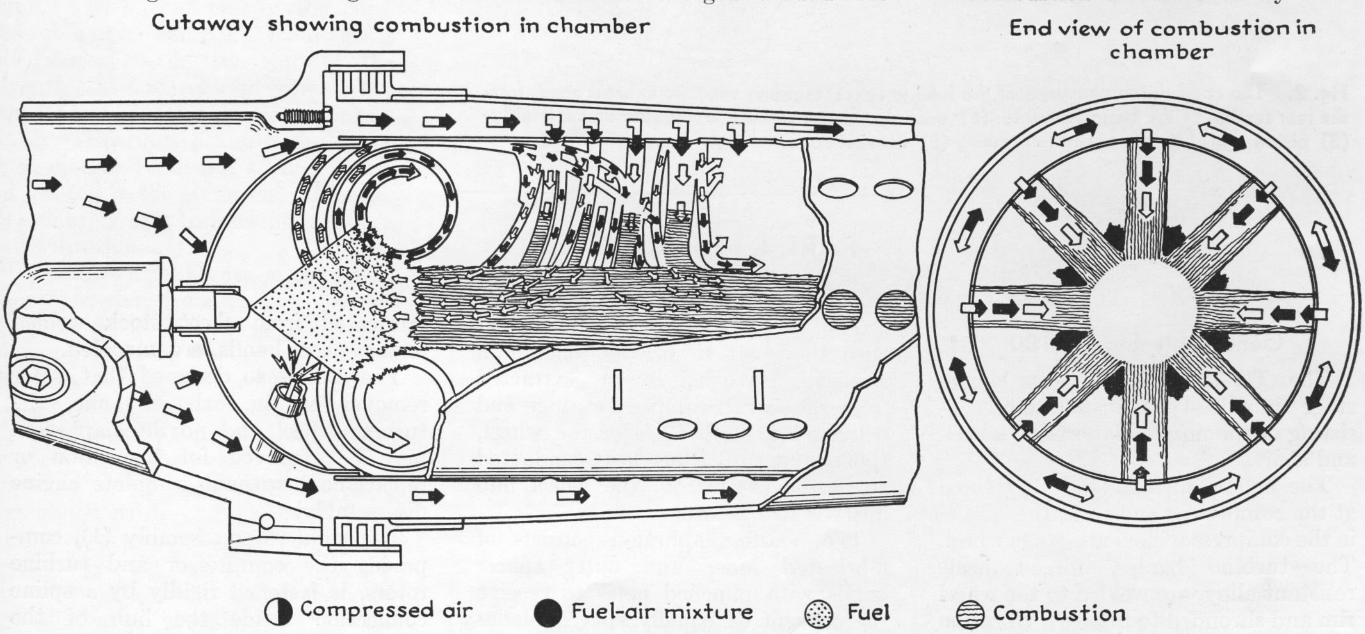


Fig. 1. Diagram of the GE I-40 combustion chamber, showing mixing and combustion of fuel and air.

in the liners, and the outer tubes are cooled by compressor discharge air before it enters the liners. A thin film of air travels the full length of the liners to provide cooling at the turbine inlet. During starting, ignition is obtained from two spark plugs mounted in diametrically opposite air adapters; ignition for the other combustion chambers is obtained by utilizing cross-ignition tubes.

Turbine nozzles are mounted between two rings around the discharge of the combustion chambers. At the entrance end of each combustion chamber, a piston ring joint is used to allow for expansion resulting from heating. The flange of the turbine bearing support (which joins to the compressor assembly) and the flange around the turbine nozzle ring (which joins to the exhaust cone) are connected by tie straps made of Invar to ensure that there will be no relaxation because of heat.

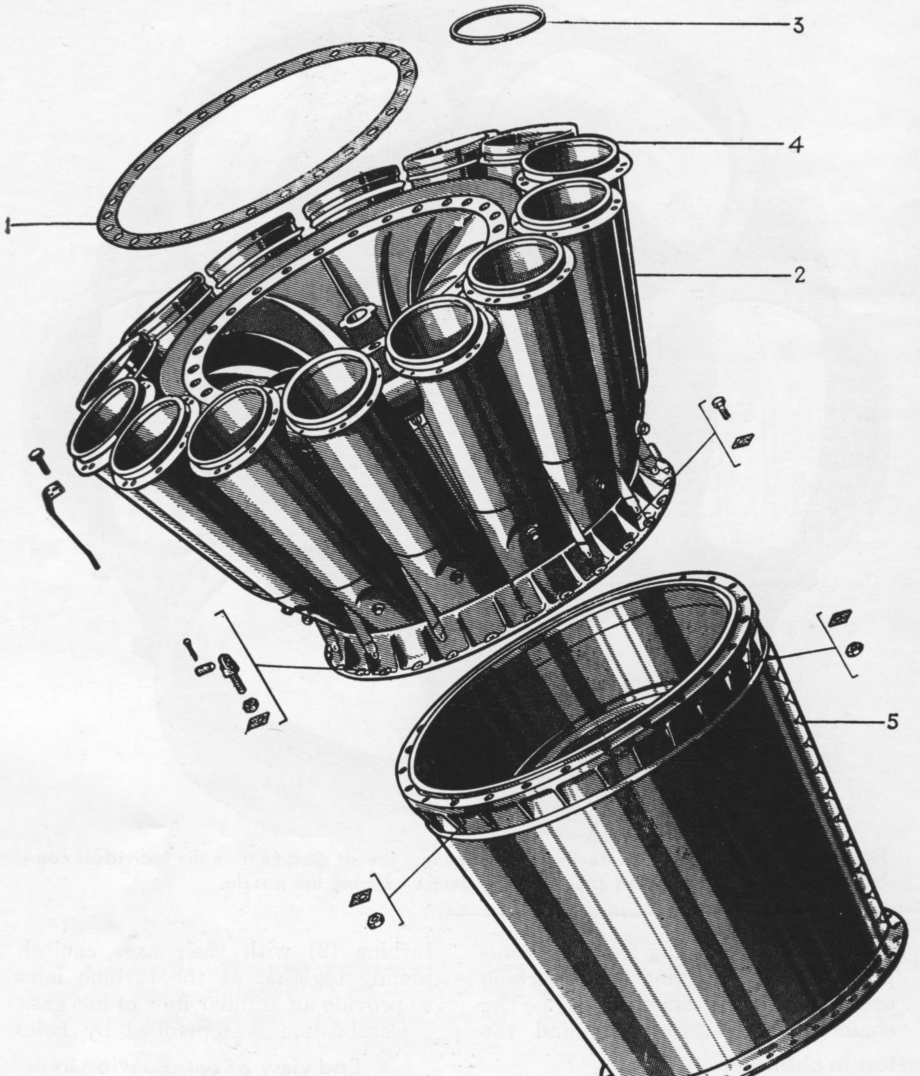


Fig. 2. The combustion chambers of the I-40 turbojet, together with the exhaust cone, form the rear section of the basic assembly: (1) bearing support gasket; (2) turbine unit assembly; (3) piston ring; (4) combustion chamber; (5) exhaust cone.

PART 4. TURBINE DESIGN

General Electric TG-180

The TG-180 turbine is a single-stage impulse-type installation consisting of the nozzle diaphragm, wheel, and shaft.

The hollow turbine shaft is splined at the compressor end to fit the splines in the compressor eleventh-stage wheel. The turbine blades, forged heat-resistant alloy, are welded to the wheel rim and shrouded to improve vibration resistance.

The turbine wheel, forged integral with the shaft to provide maximum strength, is cooled by air extracted from the eighth compressor stage and delivered to both sides of the wheel, thus helping to reduce heat conducted along the shaft from the wheel hub into the rear bearing.

The nozzle diaphragm consists of fabricated inner and outer spacer bands with punched holes to receive the ends of 64 equally spaced blades to form the nozzles. The blades, fabricated from sheet stock welded to the spacer bands, are uncooled.

The unit is so designed that, after removal of the exhaust cone, the turbine wheel and nozzle diaphragm may be removed for inspection or replacement without complete engine disassembly.

The main rotor assembly (1), comprising the compressor and turbine rotors, is fastened rigidly by a spline connection inside the hub of the eleventh-stage compressor disk to carry

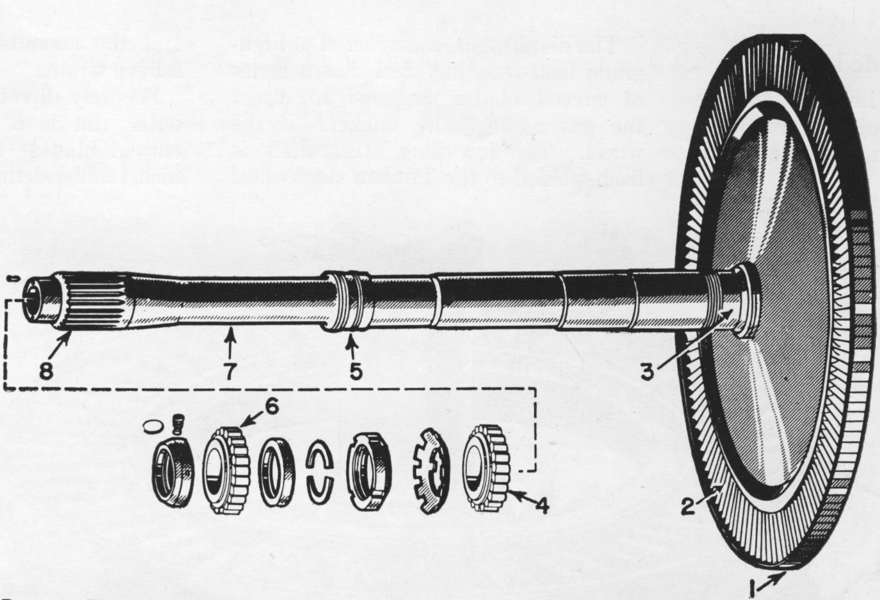


Fig. 1. The turbine rotor assembly consists of (1) turbine wheel; (2) buckets; (3) No. 4 bearing journal; (4) No. 4 bearing; (5) No. 3 bearing journal; (6) No. 3 bearing; (7) turbine shaft; (8) main drive spline, fitting into the compressor rotor hub.

torque; and by a single long bolt or drawing bar running through the hollow turbine shaft into the compressor eleventh-stage wheel hub, to carry the axial load of the turbine wheel into the compressor rotor assembly and main thrust bearing.

The main engine bearings are all superprecision quality antifriction units, for low torque and low heat rejection. The No. 1 front roller bearing is located in the forward frame on the front end of the compressor shaft. The No. 2 main thrust ball bearing is on the hub of the eleventh-stage wheel and carries the axial thrust of the entire rotor assembly. Bearings 3 and 4 are roller type, mounted on the turbine shaft and located in the aft frame. Bearing 3 is a damper unit to prevent excessive shaft vibration.

To balance axial thrust on the rotor, air is extracted from the compressor eighth stage and used to provide a balancing pressure on the face of the first-stage wheel.

Discharge gases are collected in the exhaust cone (2), consisting of a stainless-steel outer shell and central cone supported from the shell by eight streamlined struts.

From the exhaust cone end, gases pass through the exhaust pipe to the exhaust nozzle, restricted to provide high discharge velocity. It is customary to adjust the size of the exhaust nozzle to maximum permissible exhaust temperature to utilize maximum thrust obtainable from a given engine.

The length of the exhaust pipe varies with each installation and may be more than 10 ft.

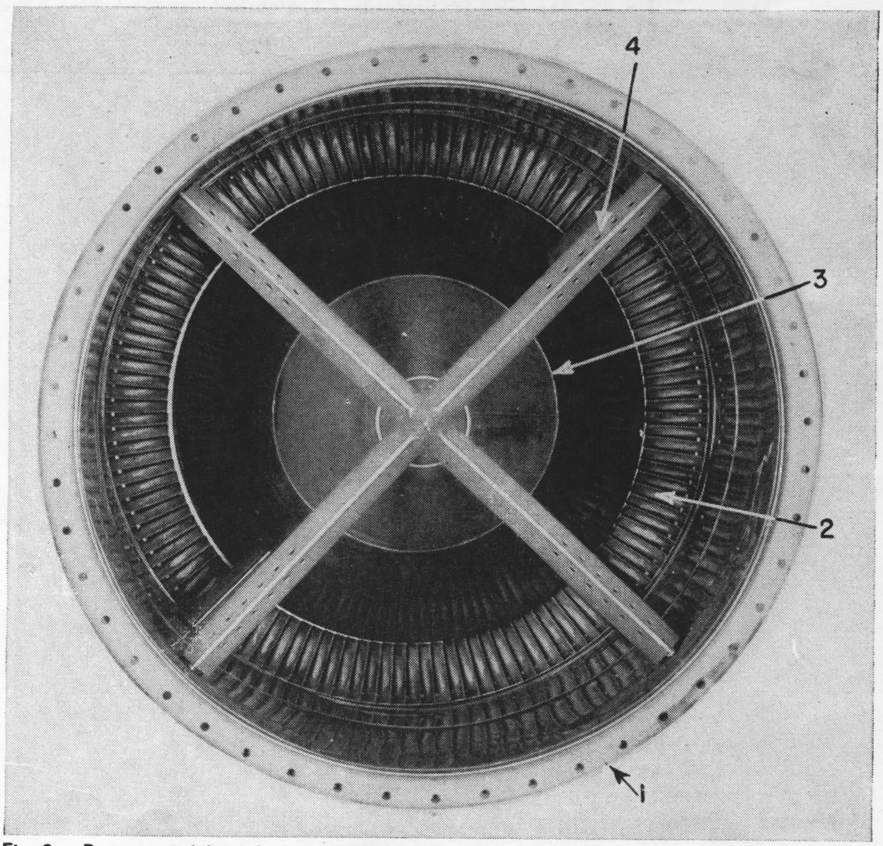


Fig. 2. Rear view of the exhaust cone of the TG-180: (1) exhaust flange; (2) turbine buckets; (3) inner exhaust cone; (4) support struts.

General Electric I-16

The single-stage impulse turbine of the GE I-16 turbojet is composed of a nozzle diaphragm, turbine wheel, and a shaft (1).

The diaphragm, constructed of high-grade heat-resisting steel, has a series of curved blades designed to direct the gas against the buckets of the wheel. The low-alloy steel shaft is flash-welded to the Timken steel wheel and the assembly is heat-treated to relieve strains.

Securely dovetailed into the wheel's outer rim is a continuous circle of curved blades—buckets—forged from nickel molybdenum alloy, Hastelloy B.

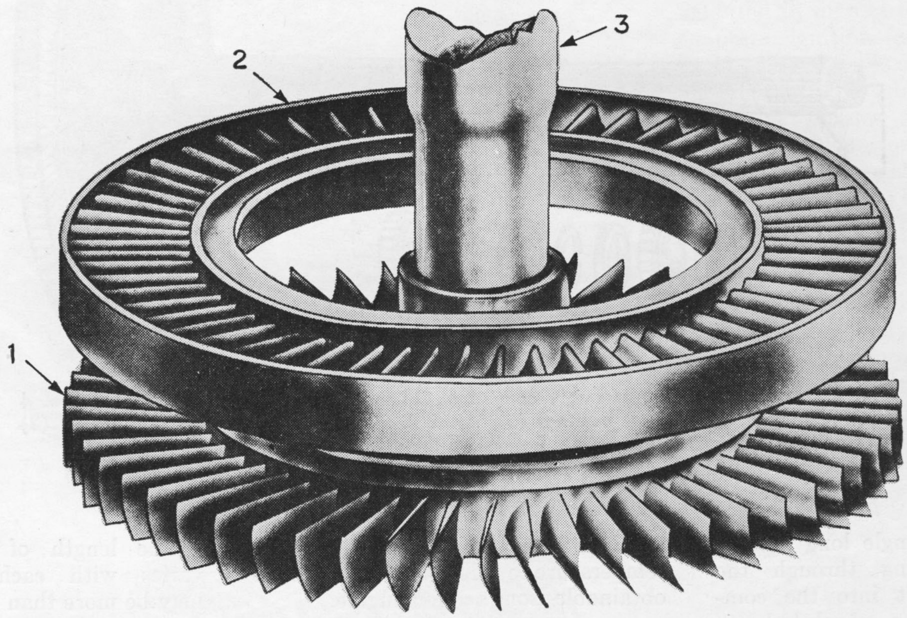


Fig. 1. The GE I-16 single-stage turbine includes (1) turbine wheel; (2) nozzle diaphragm; (3) shaft.

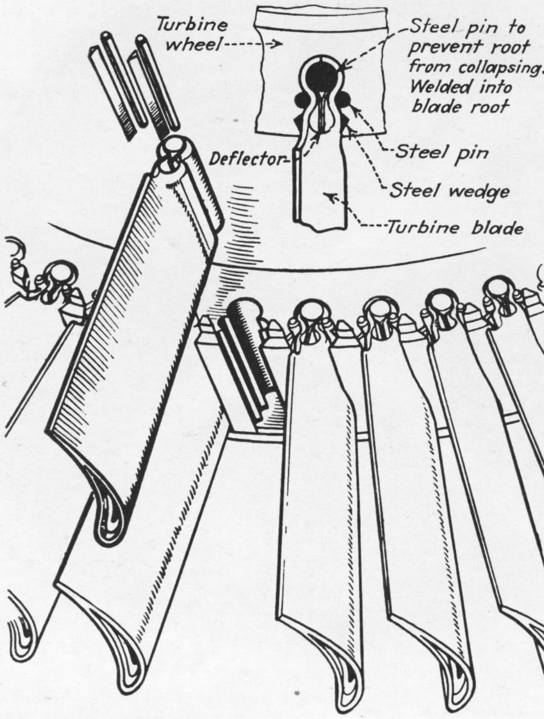


Fig. 1. Method of attachment of hollow air-cooled blades to the turbine wheel.

BMW-003

The turbine unit was considered of primary importance. The following requirements were specified by the German Air Ministry: (*a*) it must be capable of operating satisfactorily at high temperatures to secure maximum efficiency from the complete power plant; (*b*) a large flow of air must be handled by a wheel of smallest possible diameter; and (*c*) the number of stages must be maintained as low as possible.

BMW purposely confined its investigations to a single-stage type of turbine construction to expedite development. It was decided to design a unit with an average blade speed (at the center of the blade) of 820 fps and a working temperature of 800°C (1472°F) in front of the turbine.

Turbine wheels for the experimental units had a mean diameter of 20.8 in., blade length of 3.52 in., and revolved at 9,000 rpm. Early-design blades were hollow and consisted of two pieces of sheet metal welded together. The blade also was welded to the wheel.

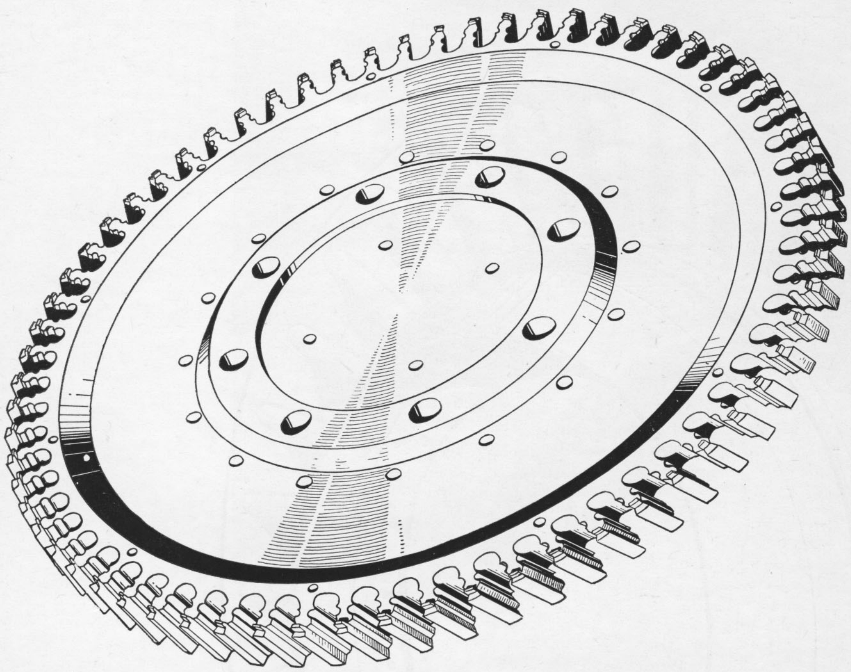


Fig. 2. Turbine wheel with machined grooves to receive blades. The first production wheel contained 77 blades; the later, model 003A-2, had 66 stronger blades.

The turbine wheel (2) was made of a chrome-moly alloy, but, to conserve critical materials, it was found that by the use of air cooling, an inferior alloy could be substituted. After the turbine blades were in place, a thin sheet-metal disk was placed on each side of the turbine wheel. Cooling air was introduced between these disks and the wheel, from a point near the turbine axle, and was exhausted through the turbine buckets, thus cooling them as well (3).

Turbine nozzle blades at first were made simply of twisted sheet metal (as is the practice with turbosuperchargers), passed through an opening in the outer ring, and welded to the inner ring. These soon became badly distorted. Sheet-metal profiled vanes (4), air-cooled from the inside, were introduced, distortion being eliminated when the cooling air was made to exhaust through the T.E. of each blade.

However, vibration fractures often occurred at the point where the blades were welded to the nozzle ring, and this difficulty had not been overcome when production ceased as a result of American occupation.

However, as the quality of the weld could not be relied upon, it was necessary to attach the blade to the wheel by mechanical means. Forged blades gave much longer life, but because of fabrication difficulties, they could not be adapted to mass production and were discarded in favor of an air-cooled sheet-metal blade of improved design.

Hollow sheet-metal air-cooled turbine blades used in production were made from a chrome-nickel alloy. The alloy was cut in long sections having a width approximately that of the blade height, and the strip was then taper-rolled to a thickness of 2.7 mm on one end and 0.6 mm at the other, cut to proper length, bent in a die, and folded over. The trailing edge was welded by the atomic hydrogen process.

Ten additional operations finished the blade, with cooling insert. The blade was attached to the turbine wheel with dowels and wedges, so that centrifugal pressure from rotation of the wheel held the bucket firmly in place (1).

Cooling air flow used on the turbine wheel and buckets amounted to approximately 1 per cent of the total air flow through the unit.

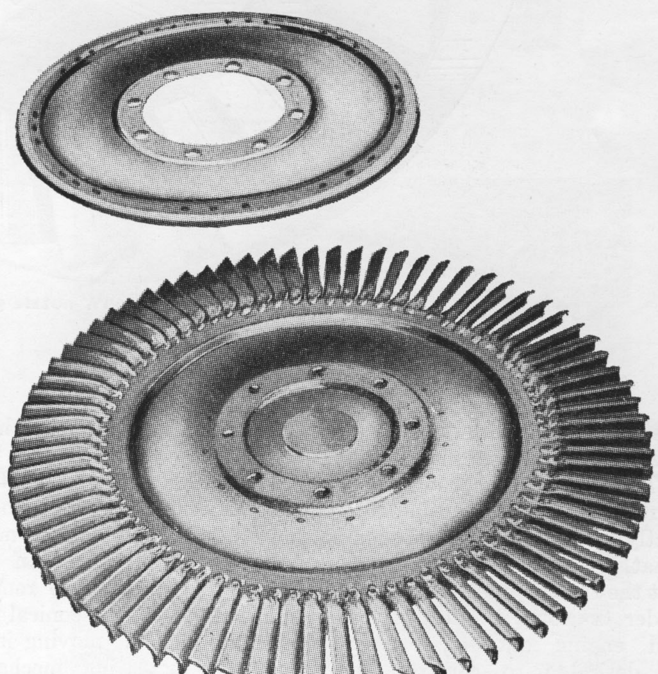


Fig. 3. Turbine wheel with blades attached. A sheet-metal disk is applied to each side of the wheel to guide cooling air to the blades.

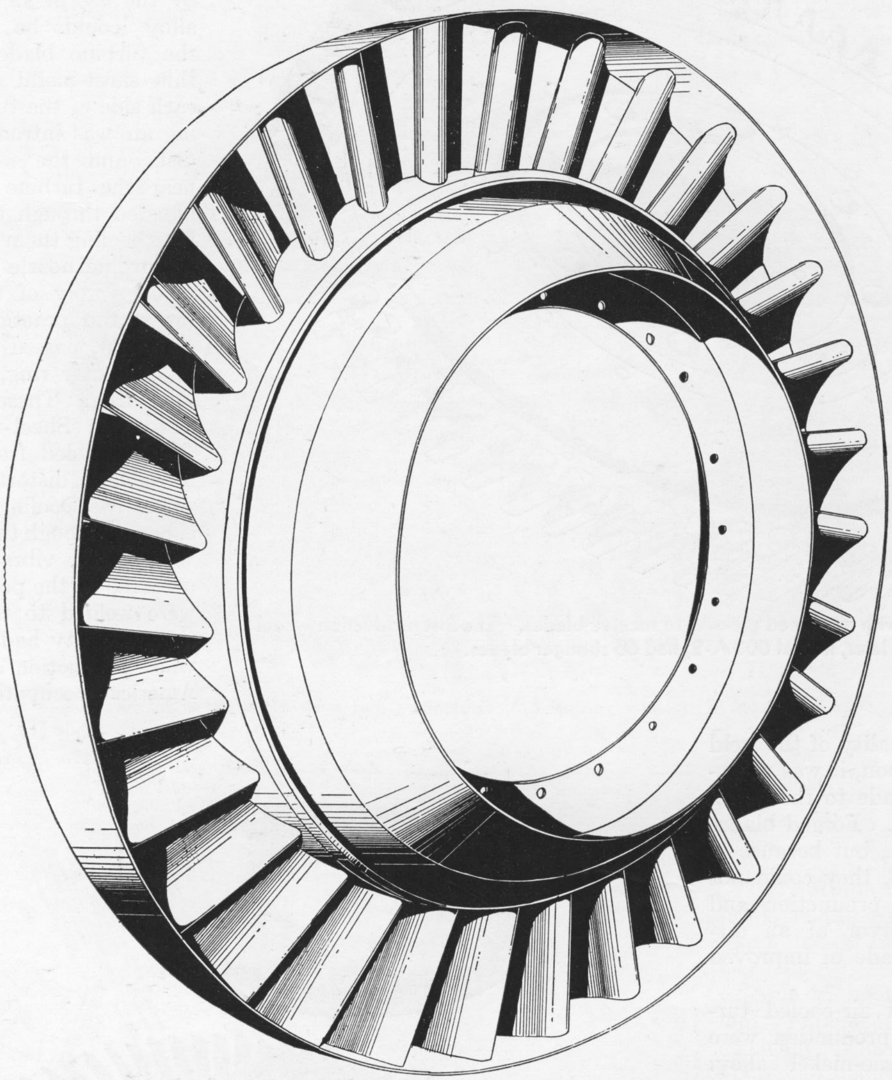


Fig. 4. Front view of the BMW nozzle guide vane assembly.

Tests were carried on with stationary thrust nozzles in early experimental engines. This simplified construction and the exhaust outlet area could be made exactly as desired. It was soon evident that, to control the gas temperature at the turbine inlet—a critical point—under various conditions of flight and engine output, it was extremely desirable to control the thrust nozzle area by having a movable streamlined "bullet" in the exhaust cone (5).

Distortion occurred in the bullet, and failures from overheating occurred in the rack and pinion moving the bullet in and out. An improved design was adopted to remedy these difficulties, with the conical mushroom or bullet element moving in and out, and the regulating mechanism air-cooled to ensure free operation. The total distance traveled by the bullet element was 4.2 in., which changed the thrust nozzle area from 155 to 220 sq in.

The thrust nozzle was made from deep-drawn 1010 sheet metal. After fabrication by spot-welding, the entire assembly was sprayed or dipped in aluminum lacquer and baked at a temperature of 400°C.

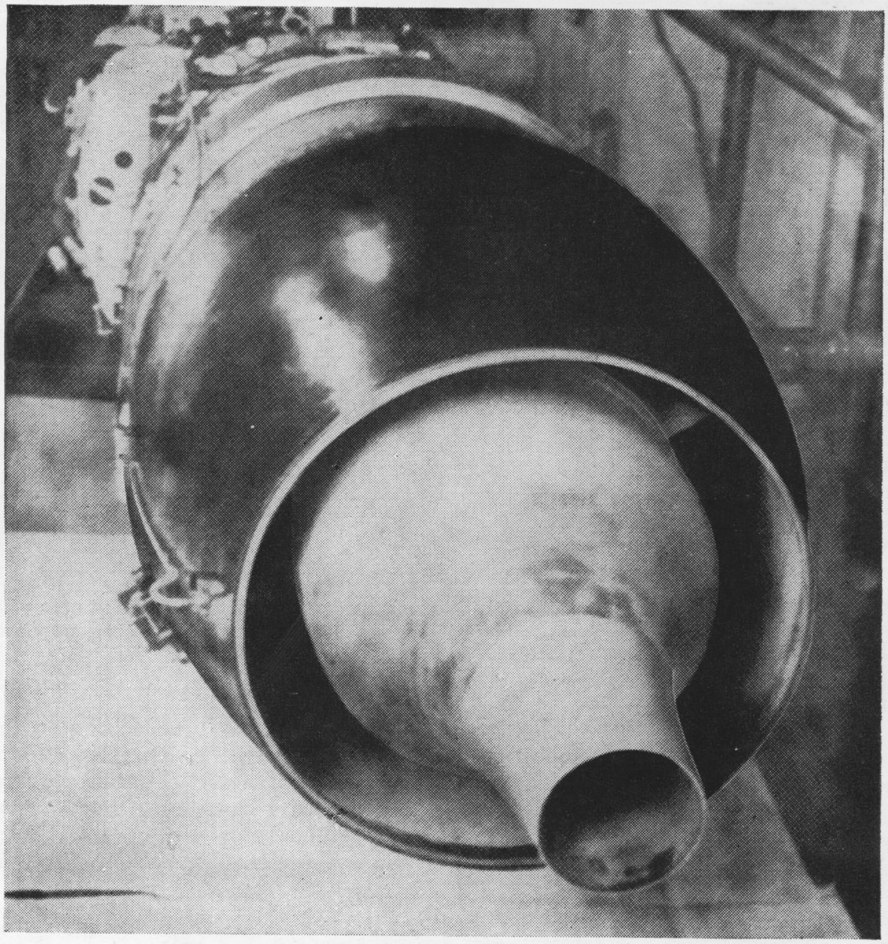


Fig. 5. Rear view of the 003 jet engine, showing the exhaust nozzle and "bullet."

Westinghouse 19-B

The Westinghouse Yankee turbine nozzle assembly (1) is composed of 45 Vitallium nozzle vanes held loosely—to permit thermal expansion—in slots in concentric steel shroud rings. The whole unit fits into the rear of the combustion chamber between the No. 3 bearing sleeve and the outer casing.

The outer shroud ring is machined to fit below the chamber flange face, thus facilitating the attachment of the exhaust nozzle. This shroud ring is held in place by four lugs, similar to those on the inlet guide vane assembly; the inner ring by six tap bolts, also similar to those on the inlet guides.

The turbine disk, shaft, and coupling flange are machined from a single Cyclops 19-9-W-MO forging. The shaft coupling has a machined face with counterbored and chamfered female spigot for positive alignment, and is attached to the compressor by

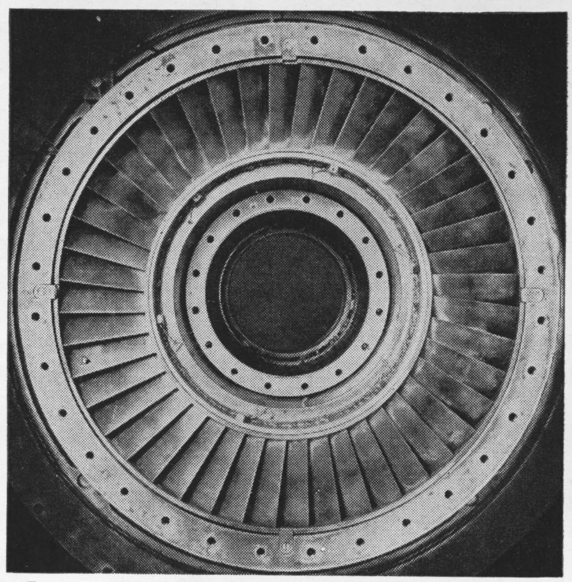


Fig. 1. Westinghouse Yankee turbine nozzle assembly showing the lugs which hold the outer shroud ring in place and the tap bolts securing the inner shroud ring

ten ½-in. fitted bolts. No universal-joint effect has been found necessary in the coupling.

Two vertical thrust faces, finish-machined and polished from an increased shaft OD, are aft of the coupling for the thrust (No. 2) bearing. Just forward at the disk is the polished journal for the turbine (No. 3) bearing.

As on the compressor, the 32 turbine blades—K-43-B machine- and hand-finished forgings—have bulb roots fitting into milled slots in the disk and are held in place by peening the shank of the root into chamfers at each end of the slots (2).

The thrust bearing (3), which also carries the radial loads, is a cast-steel housing containing lube and scavenger oil connections and holding babbitt sleeves and babbitt-covered radial faces to take the axial thrust.

The turbine bearing is a cast-steel housing split along the horizontal outer line with a babbitt-lining sleeve grooved for oil passage. This housing is drilled and cored for both lube and scavenger passages. The bearing seals of both thrust and turbine bearings are similar to those on the No. 1 bearing.

The exhaust nozzle's outer casing is stainless steel with a welded flange at the leading edge holding it to the aft combustion chamber by 32 bolts. Surrounding the case at the turbine blade trailing edges is a welded 1-in. steel ring to give greater stiffness to the unit in an area where the clearance between the blade tips and the casing is approximately 0.0625 in.

Inside the exhaust nozzle casing are four hollow streamlined struts supporting the movable tail cone, the motion being imparted through a

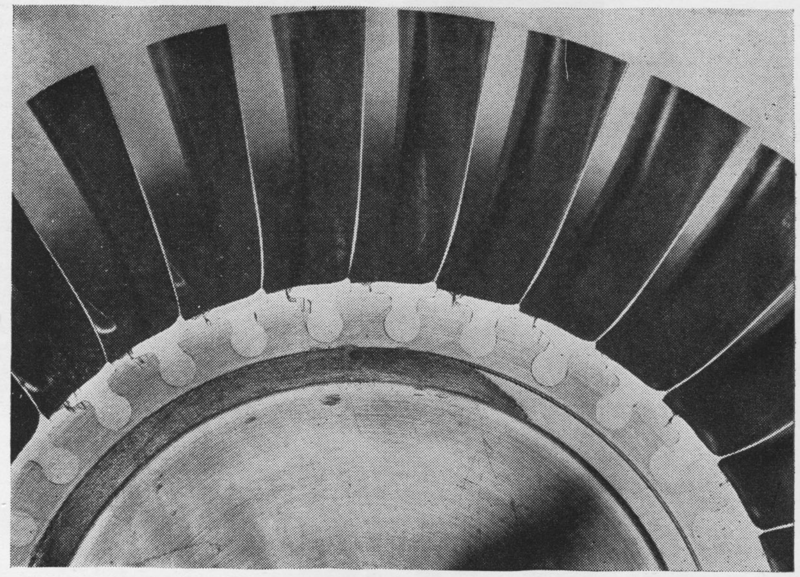


Fig. 2. The turbine blades have bulb roots fitting into milled slots and are secured by peening the shanks of the roots into chamfers at each end of the slot. The blades are machined and hand-finished.

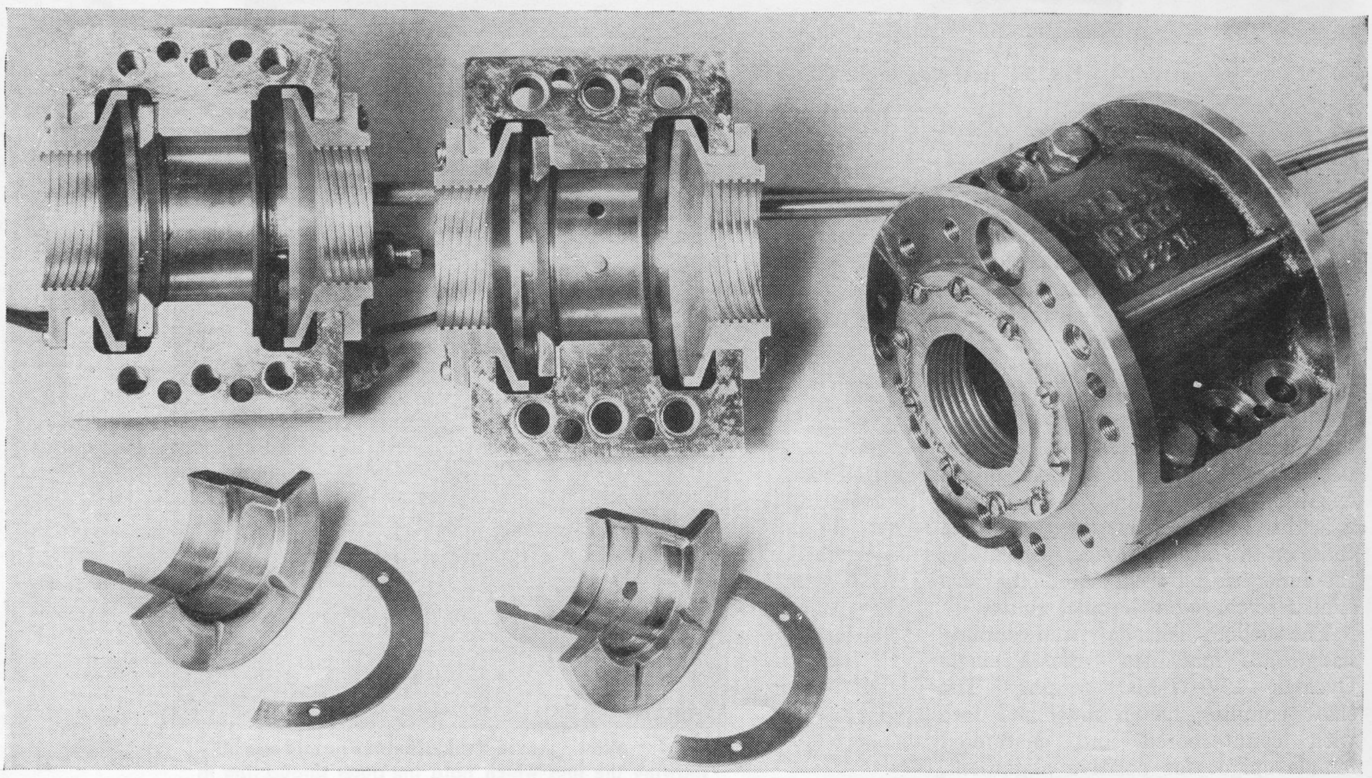


Fig. 3. This exploded view (left) shows the thrust-bearing components, which are assembled at the right.

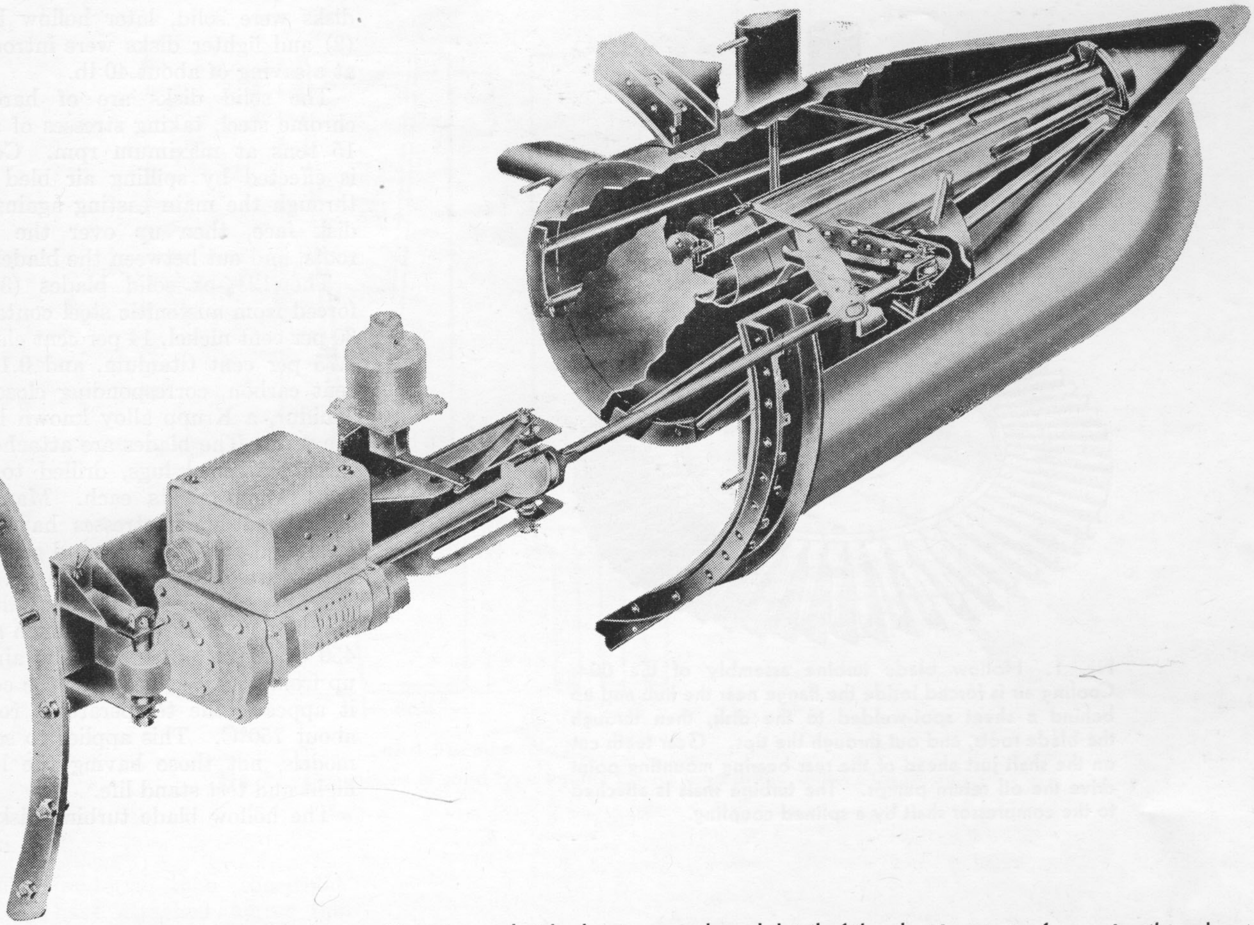


Fig. 4. Yankee 19-B exhaust-nozzle assembly cutaway sketch, showing an enlarged detail of the electric actuator for moving the exhaust cone to vary the area of the exhaust nozzle.

pivot and linkage coming out through one of the struts to connect with an electric actuator installed on the combustion chamber casing (4).

The movable cone gives greater operating efficiency, especially where rapid acceleration is required. In the "cone-in" position for starting and idling, the exhaust area is greatest, reducing pressure immediately aft of the turbine and making available the full pressure drop available to the turbine. In the "cone-out" position, the outlet area of the exhaust nozzle is reduced and back pressure on the turbine increased, thus reducing the energy available to the turbine so that higher temperatures and more fuel are required to maintain rotative speed. The additional energy thus delivered to the jet is realized in the form of an increase in velocity of the flow through the reduced nozzle area.

Junkers Jumo-004

An unusual feature of the Jumo-004 design is the use of hollow turbine nozzle blades (1) through which cooling air is fed from the compressor via the main casting and supporting diaphragm plates. Earlier 004's used solid-type blades.

The two-part outer nozzle shroud ring is made of mild steel, and both parts are welded to a ring that is joggled and flanged to mate with flanges though 36 bolts on the inlet ducting and the aft flange of the combustion chamber casing. In addition to the boltholes, the flange has 36 sets of three holes for cooling air passage.

The 35 nozzles are made of austenitic sheet steel, 0.045 in. thick, bent to shape round a $\frac{1}{16}$-in. radius to form the leading edge. Between the sheets at the trailing edge are spot-welded four wedge-shaped spacers, 1 in. long and tapering from $\frac{1}{8}$ to 0.020 in., leaving a 0.020-in. gap down the T.E. through which the cooling air escapes.

In assembly, the blade tips are closed, pushed through slots welded to the outer shroud ring, and the roots are pushed through slots in the inner shroud ring and spot-welded in place on the inner surface of the ring.

A heavy, mild-steel flange and second flanged ring are welded in turn to this ring, the two flanges picking up with the diaphragm plates which support the assembly from the rear of the main casting.

Two types of 61-blade turbines are used. Originally, both blades and

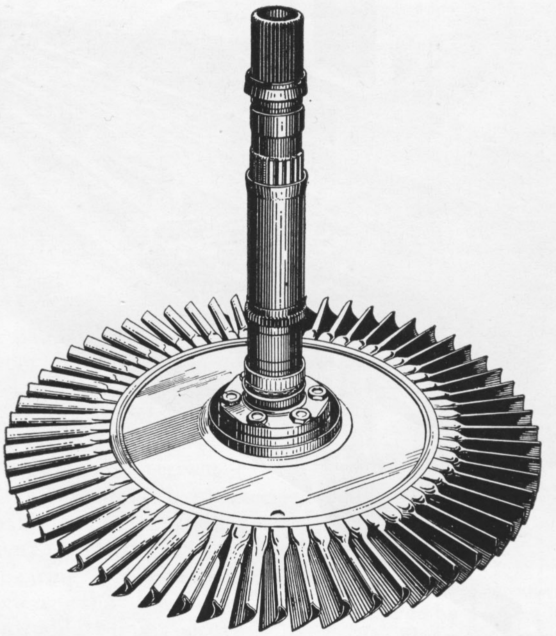


Fig. 1. Hollow blade turbine assembly of the 004. Cooling air is forced inside the flange near the hub and up behind a sheet spot-welded to the disk, then through the blade roots, and out through the tips. Gear teeth cut on the shaft just ahead of the rear bearing mounting point drive the oil return pumps. The turbine shaft is attached to the compressor shaft by a splined coupling.

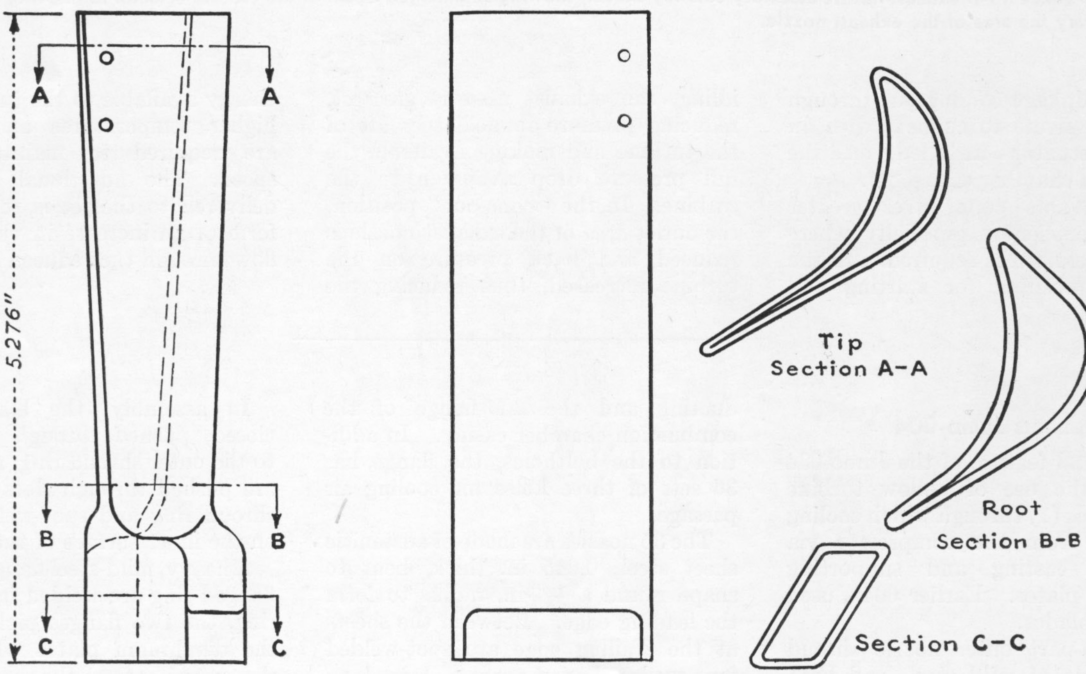
disks were solid, later hollow blades (2) and lighter disks were introduced at a saving of about 40 lb.

The solid disks are of hardened chrome steel, taking stresses of about 15 tons at maximum rpm. Cooling is effected by spilling air bled back through the main casting against the disk face, then up over the blade roots, and out between the blades.

The 12¼-oz solid blades (3) are forced from austenitic steel containing 30 per cent nickel, 14 per cent chrome, 1.75 per cent titanium, and 0.12 per cent carbon, corresponding closely to Tinidur, a Krupp alloy known before the war. The blades are attached by three machined lugs, drilled to take two 11-mm rivets each. Maximum centrifugal blade stresses have been estimated at 18,000 psi, and gas bending stresses at 2,000 to 4,000 psi.

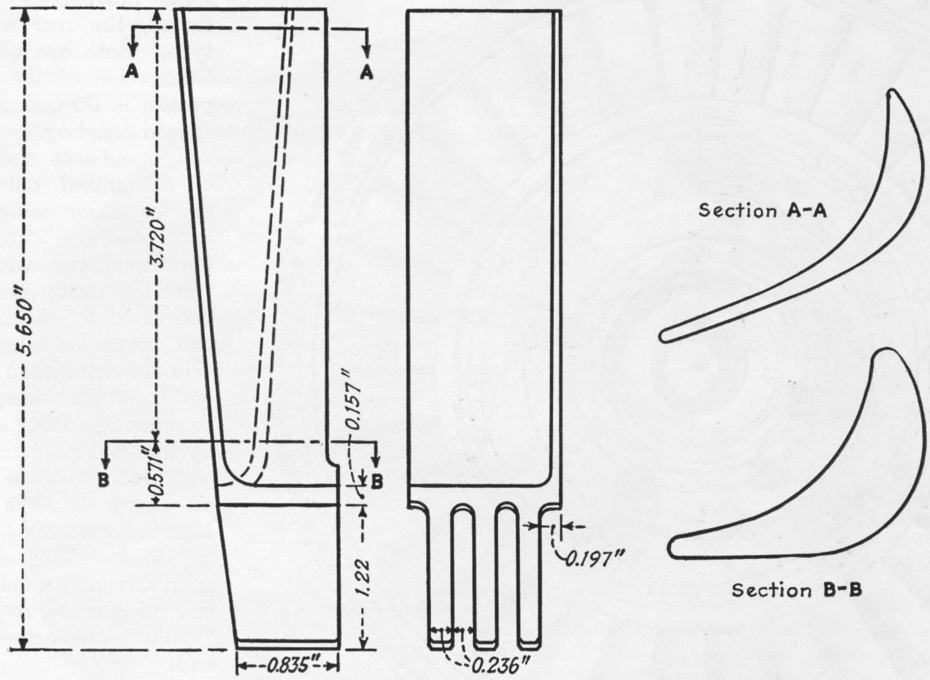
A study of the solid blades indicates that the roots did not get much above 450°C, because of the cooling air flow up from the disk, but near the center, it appears, the temperatures rose to about 750°C. This applies to service models, not those having the longer flight and test stand life.

The hollow blade turbine disks are



HOLLOW TURBINE BLADE

Fig. 2. Sketch showing hollow-type turbine blade measurements.



Solid Turbine Blade

Fig. 3. Dimensions of solid-type turbine blades used in the earlier 004 models.

of lighter material than the solid types and have attached, across the front face, a thin sheet flared out near the center. This picks up the cooling air and, via ridges on the disk, whirls it out toward the blade roots where it goes through two small holes drilled in the disk rim, up through the blade, and out the tip (4).

The hollow type, made of the same material as the solid blades, is formed by deep-drawing a disk through a total of 15 operations. In assembling the turbine, the blade roots are fitted over grooved stubs on the disk rim. Two small holes on each side take locating pins to hold the blades in place during assembly, but they take no stresses.

With a silver-base flux in the grooves, the entire unit is put in an oven at 600 to 800°C, warmed for 20 min, then heated to about 1050°C in 40 min, then cooled in still air at room temperature before hardening in a gas or air oven.

Later production units have two rivets in the blade T.E. near the tips, a modification made necessary by cracking caused by vibration.

The turbine is attached by six studs

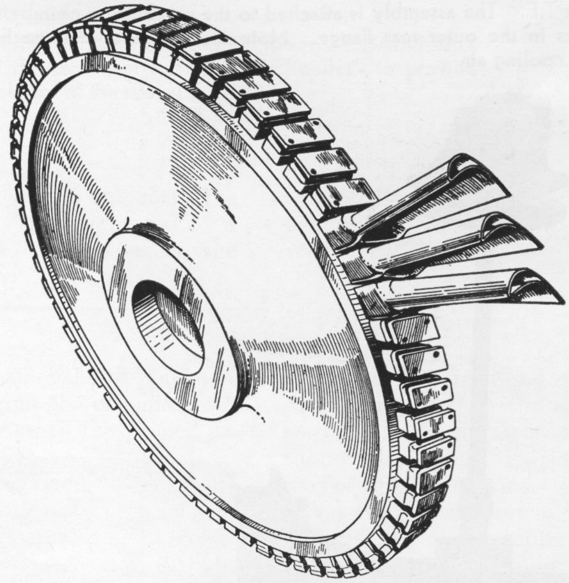


Fig. 4. Turbine disk detail sketch illustrating the method of attaching hollow blades. The groove in the disk stub is filled with special high-temperature silver-base brazing flux. The blade is then pinned into place, and the entire unit heated. Two small holes on the ends of the disk stubs direct cooling air through the blade roots.

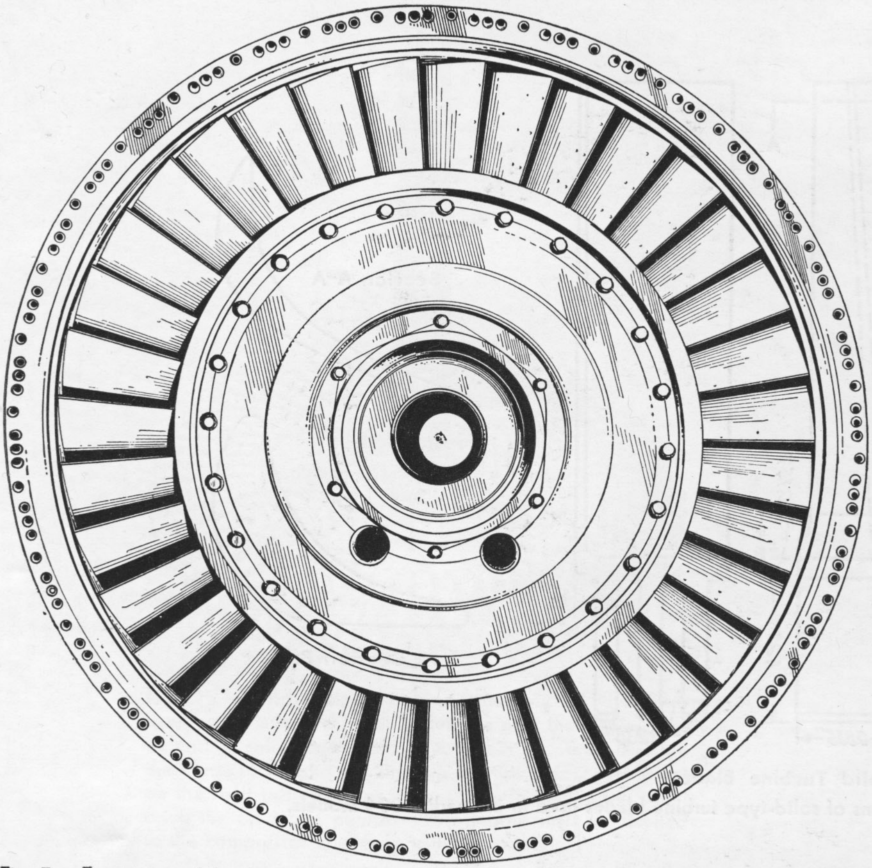


Fig. 5. Front view of the Jumo-004 turbine nozzle assembly showing the rear turbine bearing and the diaphragm plates in place. Cooling air enters two holes seen just below the bearing, goes up between the diaphragm plates and through the nozzle roots, and goes out through openings in the T.E. The assembly is attached to the combustion chamber casing by means of 36 boltholes in the outer rear flange. Note the 36 series-of-three holes for carrying exhaust system cooling air.

to a short shaft carried on two bearings housed in the main casting (5). The front bearing is a single-race ball thrust, the rear a single-race roller type. Both are cooled by oil alone. Connection of the turbine and compressor is through a heavy, internally spliced coupling.

The exhaust cone (7) is made up of aluminized mild steel, consisting of two major components: outer and inner fairings. The outer fairing is double-skinned, with cooling air bled from the compressor flowing between the skins to within 15¾ in. of the exit where the inner skin ends. Outside the other skin from there to the end is another skin, flared at the L.E. to scoop in cooling air. It is attached by spot-welded corrugations.

Attached to the outer fairing by six faired struts is the inner fairing, tapering from 19½ in. at turbine end to 9¾ in. This unit houses a rack gear, driven by a shaft entering through one of the struts, which moves a "bullet" (6) extending from its aft end.

Actuating this bullet over its maximum travel of about 7⅜ in. varies the exit area between 20 and 25 per cent. It is set in a retracted position for starting to give greater area and aid in preventing overheating, then moved

Fig. 6. Top view of the "bullet" which travels fore and aft in the exhaust cone to give variable-area exit. Rack gear and gearbox for the servo motor drive are at the left.

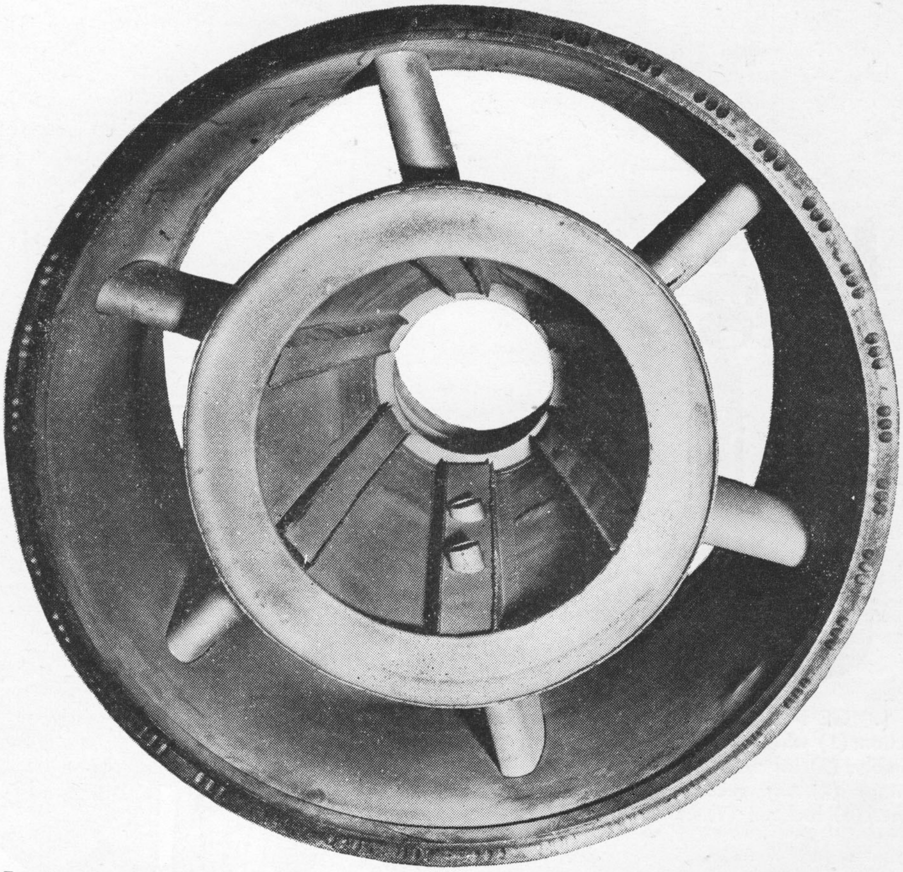


Fig. 7. Exhaust-cone front end showing cooling air holes in the outer flange and faired struts supporting the inner structure which houses the rack gear for moving a "bullet" to provide variable-area exit. Cooling air inlets are at the root of the strut at the right.

aft to decrease the area to give greater velocity for take-off and flying.

The movement is accomplished by a gear-type servo motor set near the accessory housing and connected by a long torque tube to gears set on the exhaust housing over one of the struts leading into the previously mentioned rack gear.

General Electric I-40

The I-40's turbine nozzle ring, containing 48 blades, directs the hot gas into the turbine wheel (1) equipped with 54 buckets. Exhaust from the turbine wheel is diffused in an exhaust cone (2) to a lower velocity in the circular exhaust pipe of constant diameter, which carries the gas to a jet nozzle.

In some installations, the exhaust pipe and exhaust nozzle have been combined into an exhaust pipe of constant taper from the exit diameter of the exhaust cone to the proper jet nozzle diameter.

The turbine and combustion chamber assembly includes a turbine bearing support, turbine rotor, and a set of combustion chambers. The turbine rotor's shaft is flash-welded to the wheel and buckets are dovetailed to the rim of the wheel.

The rotor is carried by a roller bearing at the rear end, and a roller bearing at the front end. Axial clearance is adjusted in the same manner as for the compressor rotor: by a sliding ring which carries the outer race of the ball bearing.

The bearing support is covered with a shroud so that cooling air can be brought along the inner wall, then passing out through the cooling fan on the front side of the turbine wheel, cool the wheel, and finally emerge through spaces of the combustion chambers.

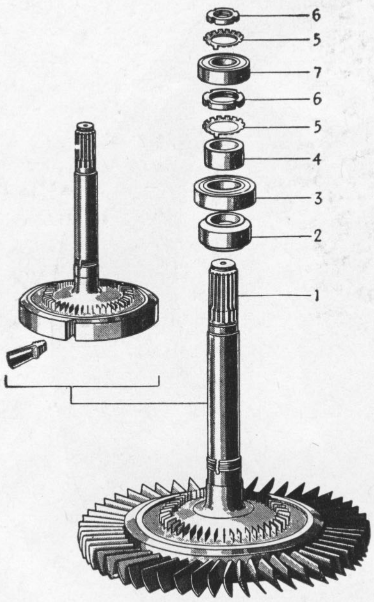


Fig. 1. GE I-40 turbine rotor construction: (1) wheel, shaft, and bucket assembly; (2) oil deflector; (3) roller bearing; (4) rear spacer; (5) lock washer; (6) lock nut; (7) ball bearing.

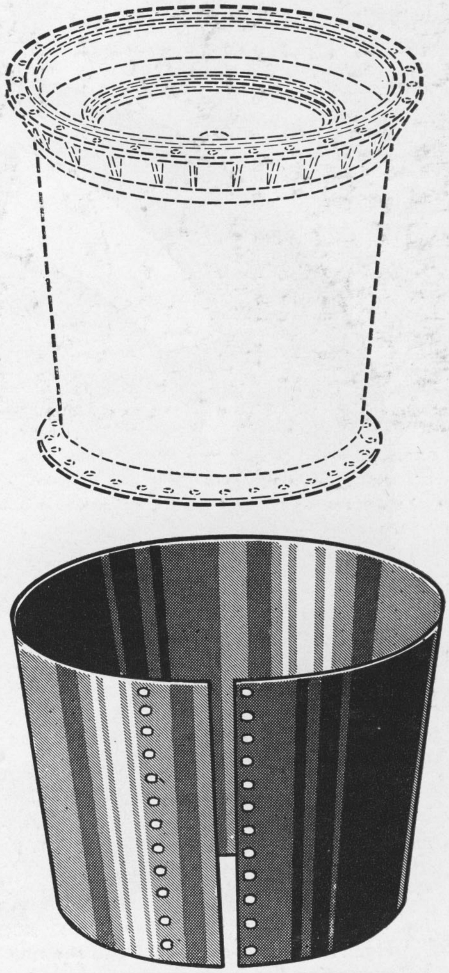


Fig. 2. Exhaust-cone assembly and aluminum foil–bronze mesh insulation pad of the GE I-40 turbojet engine.

PART 5. ACCESSORIES, FUEL AND LUBRICATING SYSTEMS

General Electric TG-180

The TG-180 accessory drive gear casing (1) is mounted at the front of the unit, bolted to the forward frame. The forward face of the gear casing has mounting pads and drives for engine and aircraft accessories, which are normally covered by a streamlined nose fairing.

Piping, wiring, and the shaft for engine speed control are brought radially outward, through the fairing and air stream, within four streamlined "islands" having fittings for connections to be made by the aircraft manufacturer.

The air-inlet screen (2) protects the compressor from pebbles or any objects which might accidentally be left in the inlet duct.

The nonrotating accessories, mounted in the accessory compartment, or on the outside of the unit, include: flow divider, ignition transformers, air filters, drip valve, thermal units, and oil filters.

The lubrication system (3) of the TG-180 is a combination of solid oil jet lubrication for the engine forward end, including the accessory drive, and air-oil mist lubrication for the aft three bearings.

Oil is taken from engine supply tank to the engine lubrication—a multiplunger piston-type pump, each piston having an oil displacement of about 1 qt per hr. The output of each piston supplies a separate jet, several of which are used to spray oil onto the front main bearing and accessory drive gears.

Oil drained from the bearings and gears into the gear case is scavenged with a separate pump element and returned to the tank. One jet also supplies oil to each of the three main rear bearings in the aft frame between the compressor and turbine.

Air extracted through filters from compressor fourth stage is also blown onto these three rear bearings for cooling and oil atomization. The air-oil mixture is drained overboard

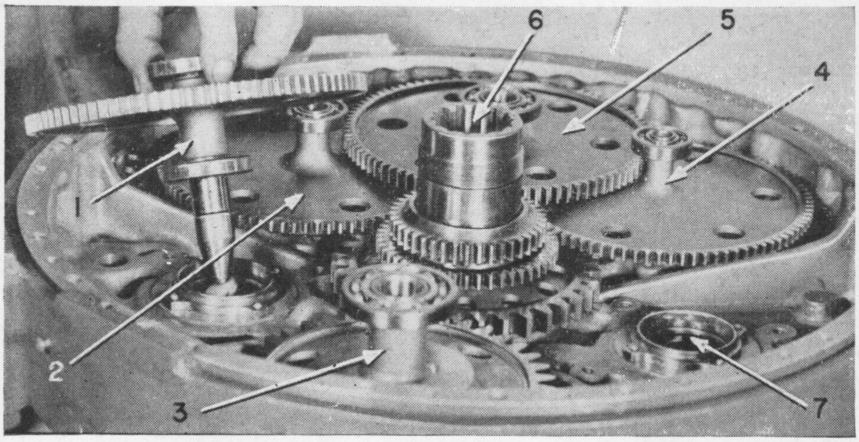


Fig. 1. TG-180 accessory gear case (rear), with cover removed, showing (1) hydraulic pump; (2) lubrication pump; (3) starter-generator; (4) tachometer generator; (5) fuel pump; (6) spline to front of compressor rotor (full engine speed); and (7) fuel-control regulator gear bearing (gear removed).

through a connection in the aft frame.

Oil is supplied to a separate pump element in the fuel pump, to provide lubrication for the latter, also hydraulic pressure for operation of the main fuel regulator. A small quantity of oil is lost through leakage in the fuel pump and the regulator, the remainder being returned to the tank (5).

The total lubricating oil consumption, including oil drained overboard, is about 9 lb per hr. No oil cooler is required, since the major part of heat rejected to the oil is carried overboard in the air-oil drain.

In the TG-180, the required variation in engine fuel flow is obtained with a variable-displacement multicylinder piston-type fuel pump. Variation of the pump displacement and, consequently, of the fuel delivered to the burner nozzles is achieved by a hydraulic plunger moving a wobble plate in the pump, varying the piston strokes. Hydraulic pressure (variable-control oil) is obtained from the fuel regulator, designed so as to maintain constant engine speed over the full range of the aircraft operating conditions for each setting of the pilot's control lever.

Components of the fuel regulator are: (*a*) A shaft for engine control by the pilot. The initial few degrees of rotation open the high-pressure stopcock or fuel shutoff valve and permit low-speed engine operation. Further rotation of the shaft increases engine speed by adjusting the mechanical setting of the governor. (*b*) A mechanical engine-driven governor incorporated in the fuel regulator to maintain constant the engine speed called for by the pilot. This device varies the hydraulic pressure delivered by fuel regulator and, consequently, the flow delivered by the fuel pump. The governor has a positive adjustable stop at the upper end of the speed range to protect the engine from rotating engine speeds higher than design speed. (*c*) Thermal units in the engine exhaust system which take over control from the governor and reduce engine speed when exhaust temperatures exceed 1300°F, thus protecting the engine from excessive temperatures. These thermal units are not operative except under extreme flight conditions.

Fuel nozzles (4) are of the duplex type, consisting of a small nozzle in each burner for low-speed and for high-altitude operations when low fuel flows are required; and a large

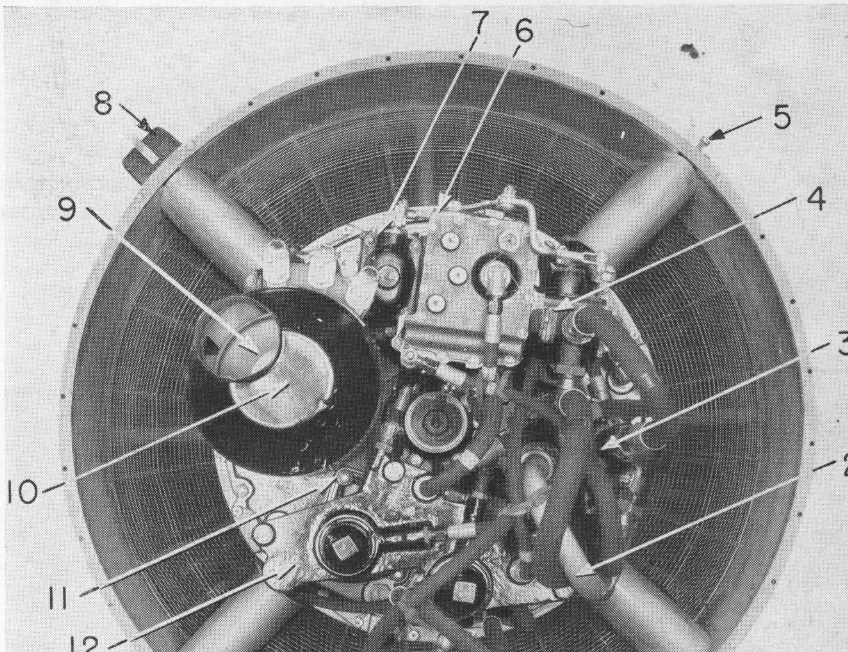


Fig. 2. Front of the TG-180 turbojet showing accessory arrangement: (1) air-inlet screen; (2) fuel-inlet connection; (3) fuel pump; (4) high-pressure stopcock; (5) engine control shaft; (6) fuel control regulator; (7) engine governor; (8) terminal box for starter-generator leads; (9) starter-generator cooling air inlet; (10) starter-generator; (11) hydraulic pump pad cover; (12) oil filter assembly; (13) accessory piping "island."

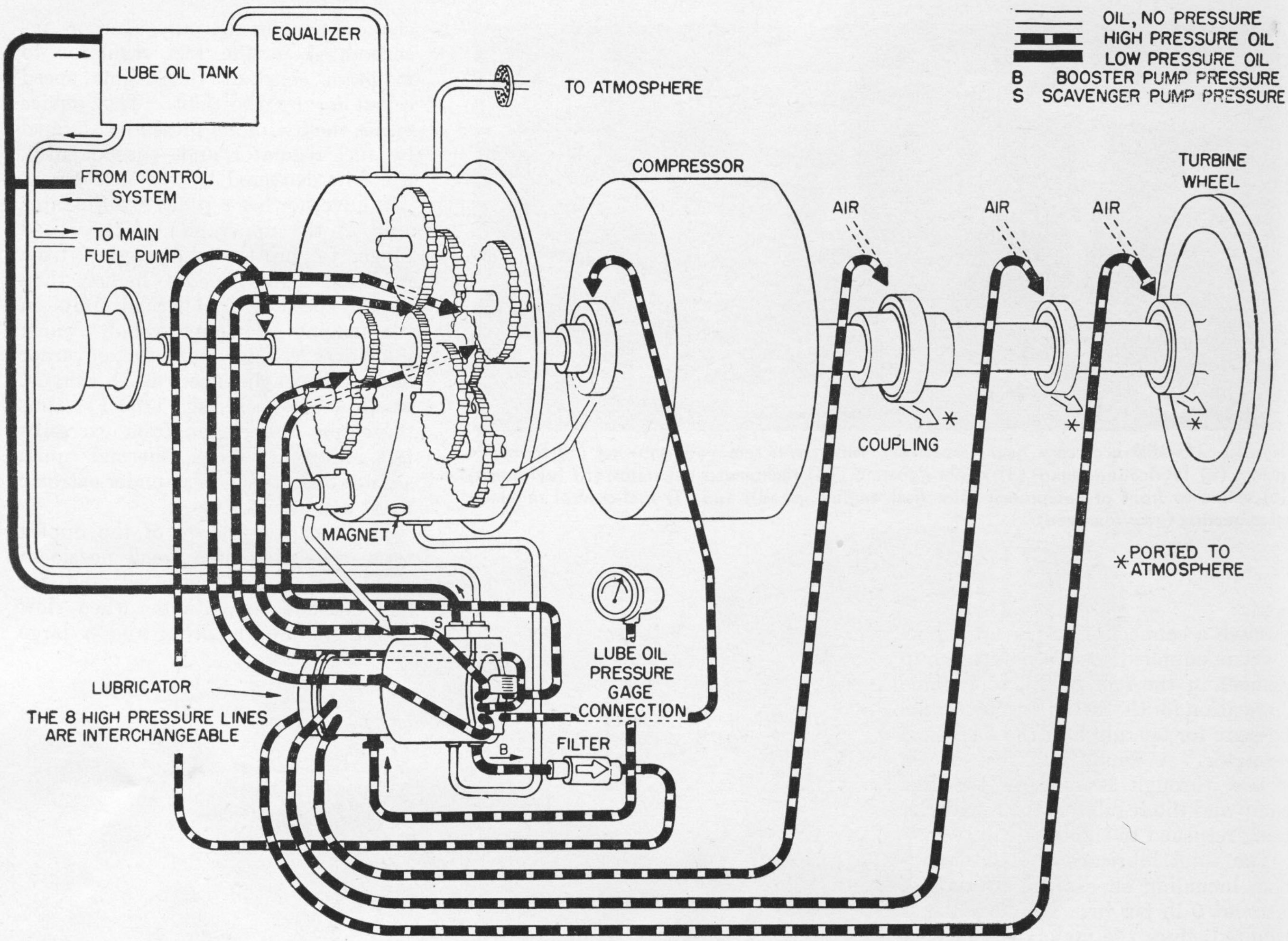


Fig. 3. Schematic diagram of the TG-180 lubrication system.

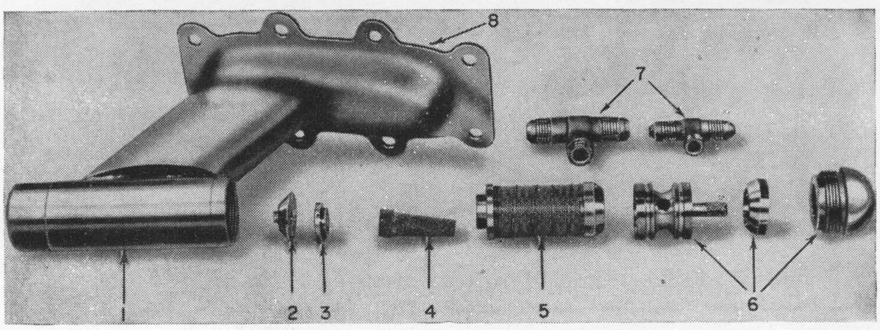


Fig. 4. Fuel nozzle details: (1) nozzle body; (2) metering orifice large slots (at sea level and high speed); (3) small slots (altitude and idling); (4) porous bronze filter for small slots; (5) wire-screen filter for large slots; (6) nozzle assembling parts; (7) fuel inlet connections on cover plate; (8) cover plate.

nozzle operating in parallel when high fuel flows are required, automatically brought into play by a pressure-operated valve, or flow divider.

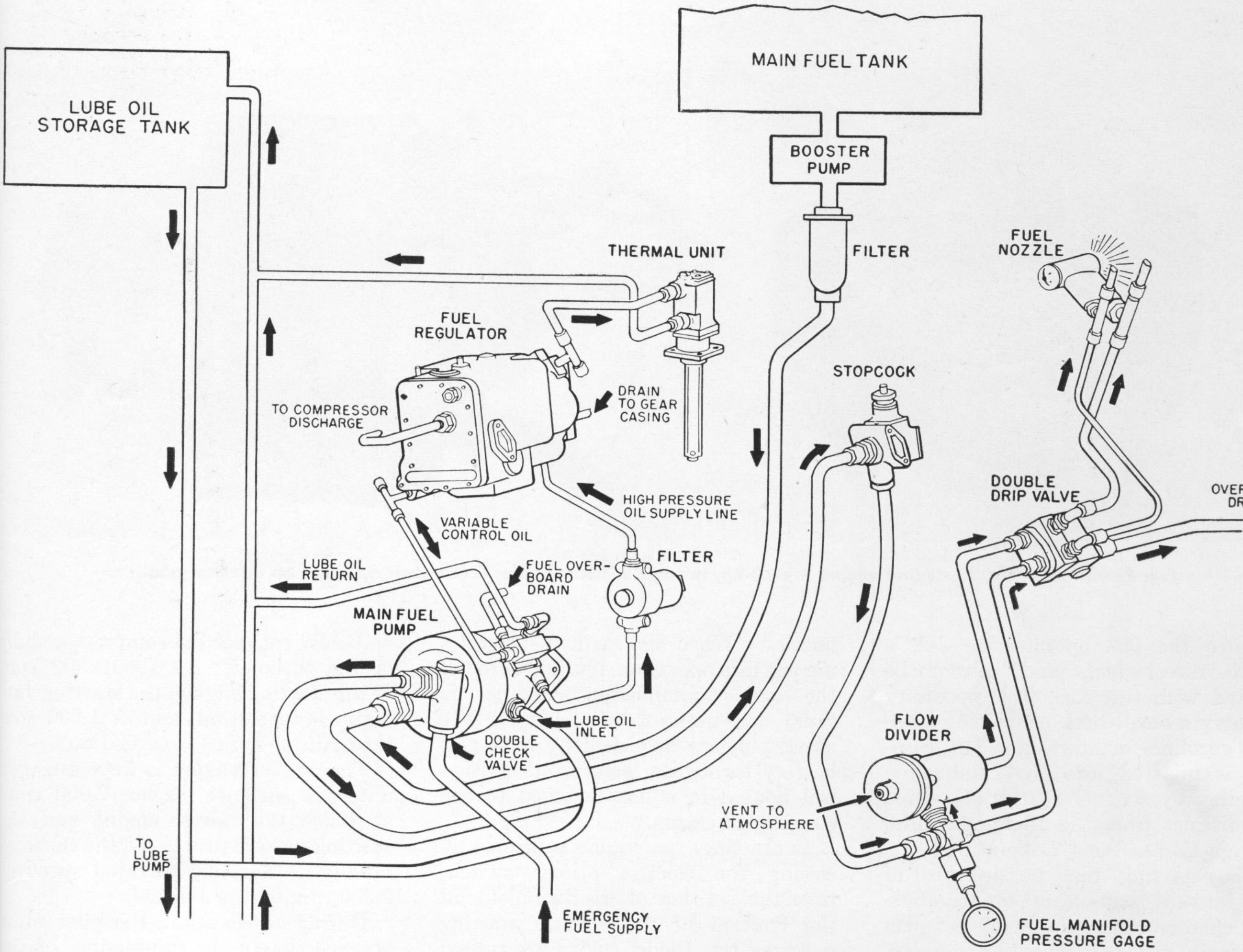


Fig. 5. Schematic chart of the fuel and oil control line in the TG-180.

BMW-003

A small, compact, air-cooled, two-cycle, two-cylinder gasoline engine is used to start the 003 jet. The unit (2), manufactured by Riedel, is mounted at the forward end of the compressor within the inlet duct. It is completely enclosed by a paraboloid-shaped hood or cowl. The starter engine operates at very high speed and can run for only a short time before overheating, but since it takes less than 1 min to complete the starting procedure of the jet, the operation need not be to a point of overheating under normal starting conditions.

The design of the centrifugal clutch, starter-dog engaging mechanism, carburetion, and electric starting assembly is rather ingenious. A small amount of lubricating oil is added to the aviation gasoline used as fuel.

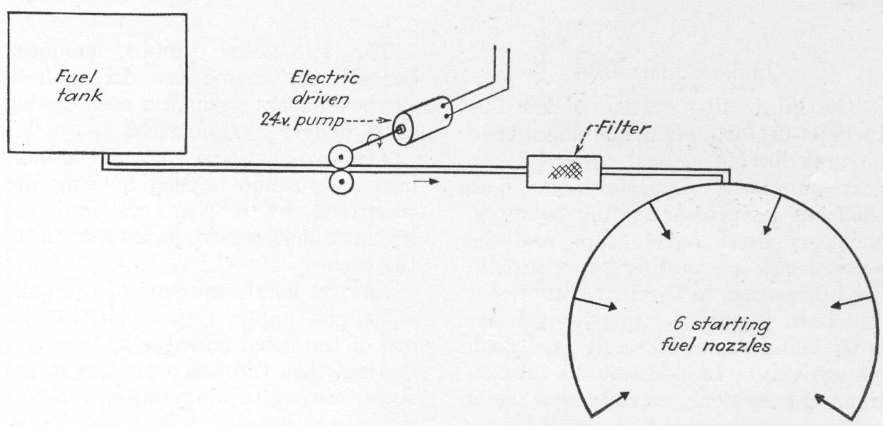
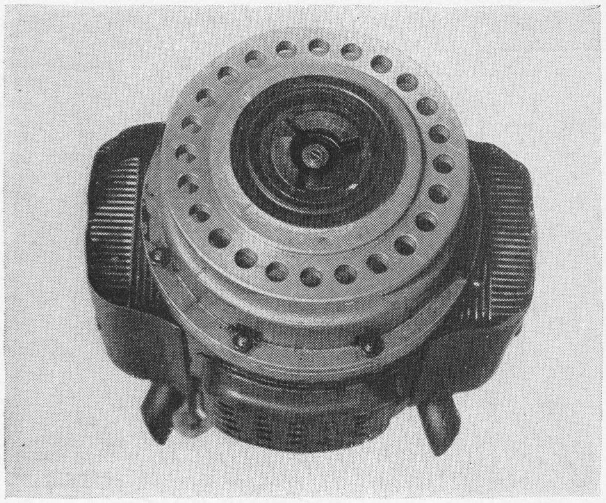


Fig. 1. Schematic drawing showing the fuel system for starting the 003 turbojet by starter engine.



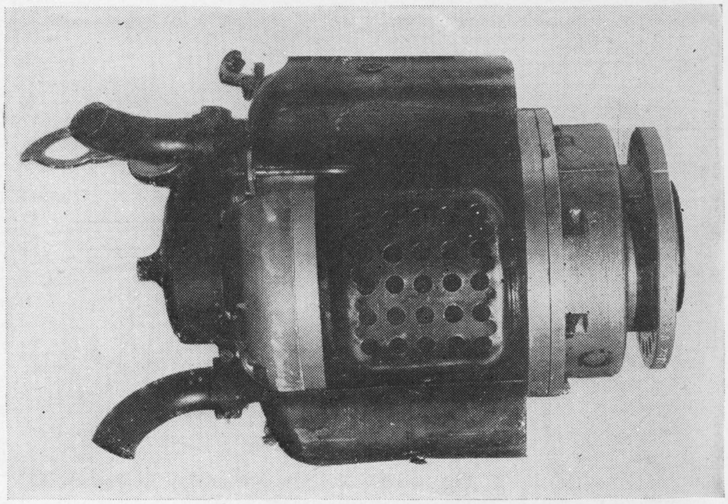


Fig. 2. The BMW-003 starting engine is a 10-hp, two-cycle, two-cylinder Riedel unit operated on aviation gasoline.

Since the 003 operates on J-2, a crude diesel fuel, and cannot be started with this fuel, it is necessary to carry a small tank containing aviation gasoline for starting. The gasoline is injected into the combustion chamber by six fuel nozzles (1) which are distinct from the 16 nozzles used for injection of the J-2 operating fuel.

The starting fuel nozzles are in the forward section of the combustion chamber, spaced equally between the main nozzles. The two topmost nozzles spray directly upon the two spark plugs, and upon ignition the flame jumps rapidly from these two ignition cones to the four other nozzles. When the main fuel nozzles are put into operation, ignition through the entire combustion chamber is rapid and uniform. Current for the spark plugs is furnished by a 24-volt battery through a buzzer and ignition coil housed in a box fastened to the compressor casing.

In starting, the engine is primed by closing the electric primer switch, then the ignition of the turbojet and the ignition of the electric starting motor of the Riedel engine are turned on (this engine also can be started manually by pulling a cable).

After the Riedel unit has reached a speed of about 300 rpm, it automatically engages the compressor shaft of the turbojet. At about 800 rpm of the starting engine, the starting fuel pump is turned on, and at 1,200 rpm the main (J-2) fuel is turned on.

The starter engine is kept engaged until the turbojet reaches 2,000 rpm, at which the starter engine and the starting fuel are turned off, the turbojet rapidly accelerating to rated speed of 9,500 rpm on the J-2 fuel.

During acceleration, the pilot must observe closely the functioning of the governor, also the temperature of the hot gas in the thrust nozzle, which must not exceed 750°C.

Junkers Jumo-004

The lubricating system of the 004 turbojet (2) includes an annular-shaped oil tank having a 3-gal capacity, two gear pumps to circulate lube oil to the front compressor bearing assembly, accessory drive bevel gears, and the accessory gears, another pump supplying lubrication to the rear compressor and both turbine bearings, the latter two being sprayed and splashed, respectively. In addition to lubrication, the system is employed as a cooling medium and cools the rear compressor and turbine bearings as well as lubricating them. The oil tank is attached by 23 bolts on a flange to the aluminum alloy intake casting.

The two main pumps, mounted beneath the engine and driven from the bevel gears through a nose casting strut, deliver 190 gph each.

The two-part scavenge unit is built into the turbine bearing housing and is driven by a gear cut into the sleeve which serves to return oil to the cooler.

In level flight, one part of the unit, a 300-gph pump, returns oil through one of the cored passages in the main casting, then through a passage in the stator casting to the pump in the bottom of the intake casting. In climbs, the other part, a 90-gph gear pump, picks up the oil and feeds it into a common return line to the air-oil separator by a 300-gph pump driven by the same shaft as the delivery pumps.

Two types of fuel are used: gasoline for starting, and J-2 brown coal "crude" for running. The gasoline is carried in the lower part of the annular tank set in the nose of the cowling and is automatically cut off after ignition at about 3,000 rpm. This is fed by an electrically driven pump delivering 90 gph at 28 psi (1). Toward the end of the war, it was found that centrifugal crude oil was also used as operating fuel.

The main single-stage electrically driven gear-type pump has a maximum delivery of 500 gph at 1,000 psi, 3,000 rpm.

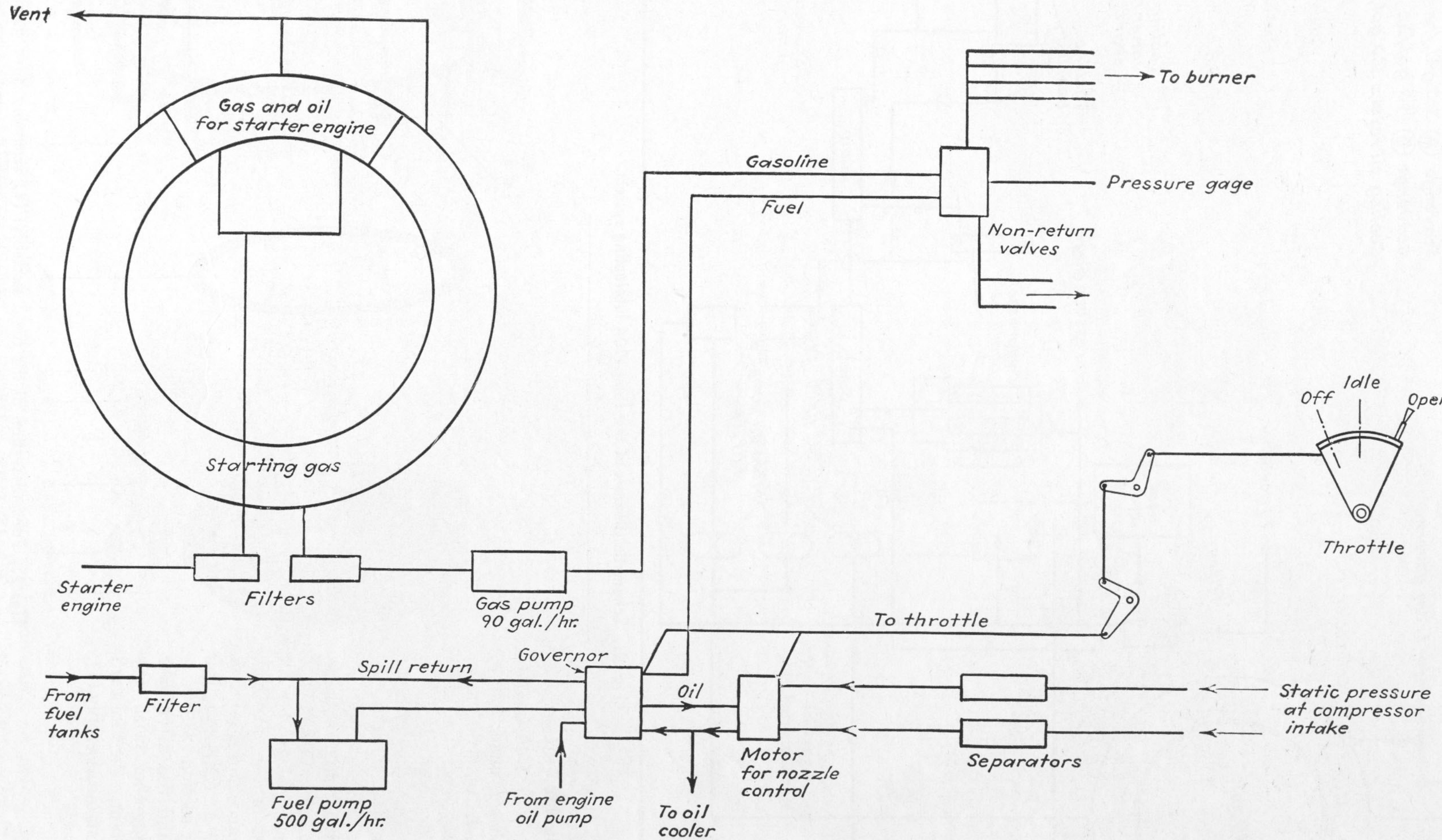


Fig. 1. Diagrammatic view of the fuel and exit area control system of the Jumo-004.

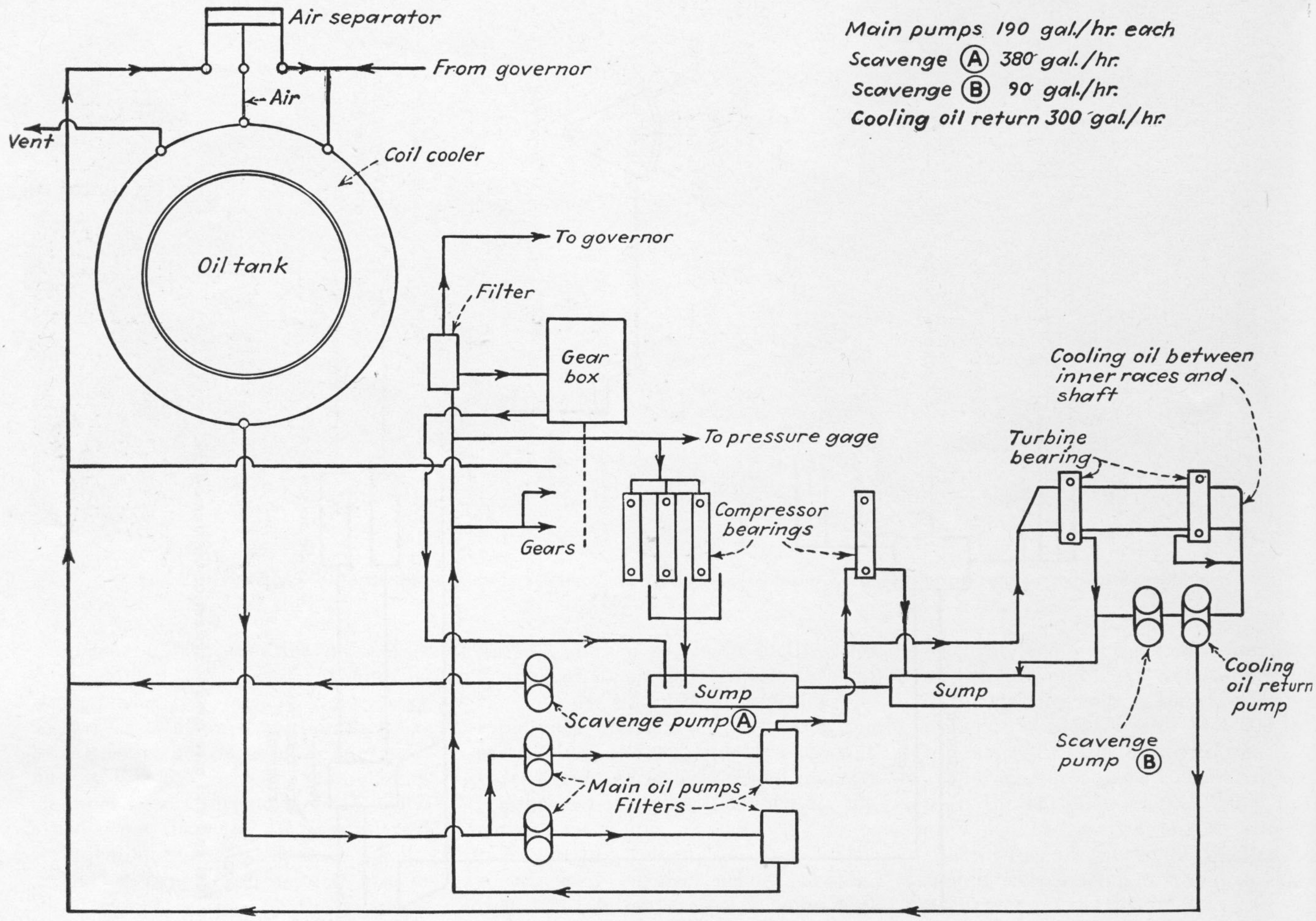


Fig. 2. Schematic diagram of the Jumo-004 lubricating system.

General Electric I-40

Accessories of the GE I-40 include the starter, lube and scavenger pump, starting fuel pump, barometric valve, tachometer generator, generator, main fuel pump, governor, control valve, and lube-oil filter. An accessory drive gear casing carries the various accessories (2).

The accessory drive system consists of the outer casing and a rotor cage which fits in the casing, carrying all the gears and most of the bearings. The gears in the accessories section are connected by a shaft to the impeller in the rotor section (3).

The accessories and the drive gear casing comprise, together with the fuel manifold system, the forward section of the basic engine assembly (1).

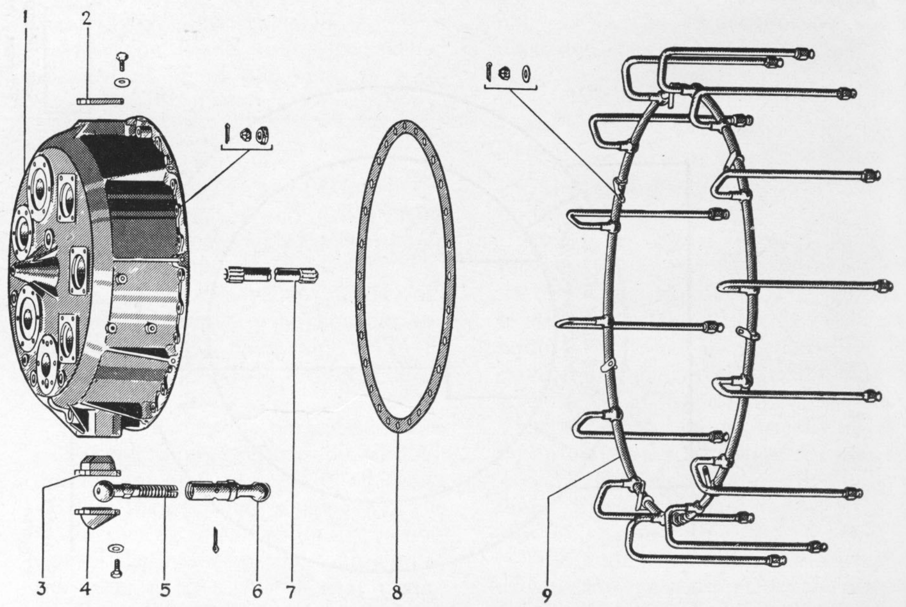


Fig. 1. Forward section of the basic assembly: (1) accessory drive gear casing; (2) support pad plate; (3) ball seat; (4) ball cap; (5) male support; (6) female support; (7) coupling shaft; (8) bearing support gasket; (9) fuel manifold assembly.

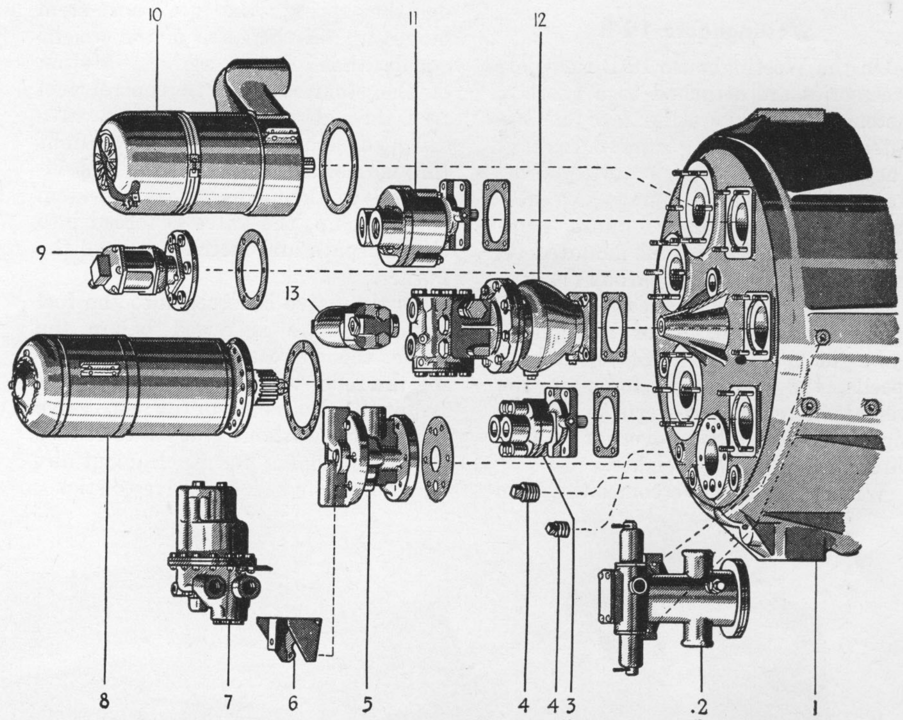


Fig. 2. Exploded relation of I-40 accessories: (1) accessory drive gear casing; (2) control valve; (3) starting fuel pump; (4) plug; (5) lube and scavenger pump; (6) bracket for barometric valve; (7) barometric valve; (8) starter; (9) tachometer-generator; (10) generator; (11) main fuel pump; (12) governor; (13) lube-oil filter.

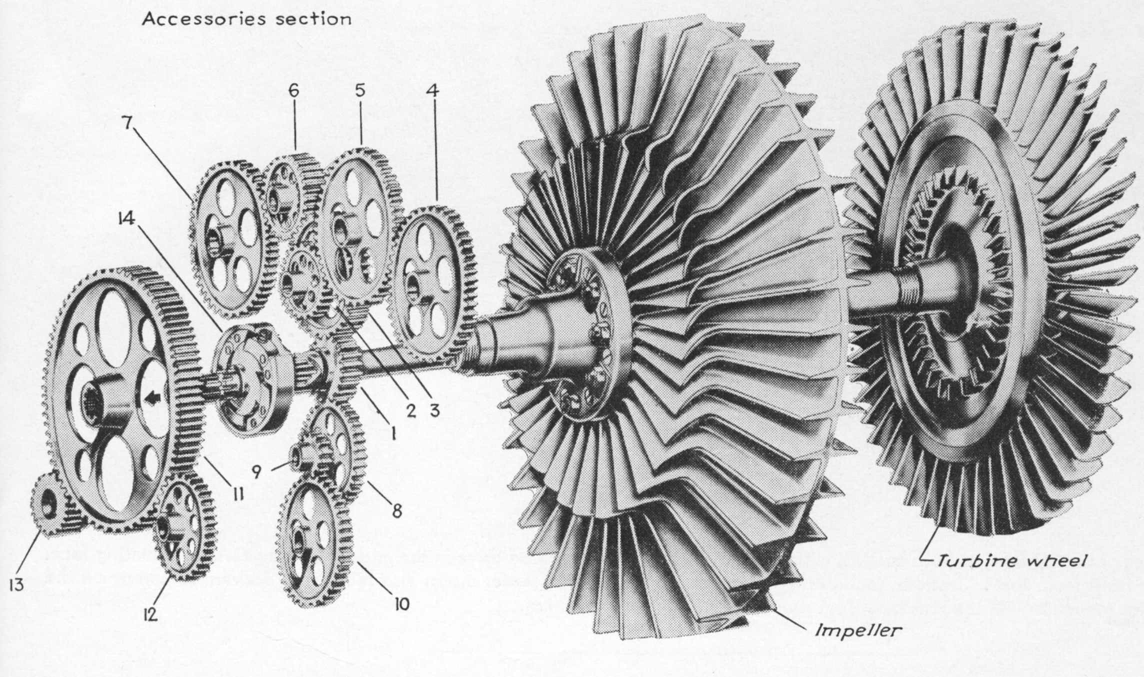


Fig. 3. Accessory drive gear train and drive from the turbine and compressor rotors: (1) main accessories pinion; (2) upper pinion; (3) upper idler; (4) governor; (5) main fuel pump; (6) generator; (7) tachometer; (8) lower idler; (9) lower pinion; (10) lube pump; (11) starter; (12) starting fuel pump, (13) starter shaft. The starter clutch is at (14).

Westinghouse 19-B

On the Westinghouse 19-B turbojet, accessories are attached to a gearbox fastened to a mounting face on the outside of the bearing support casting. They include an electric starter, generator, fuel pump, oil pump, governor, vacuum or hydraulic pump, and tachometer generator, all mounted on the aluminum casting gearbox (1).

The governor, designed to protect against overspeed, is of mechanical flyweight type. As it rotates at high speeds, the centrifugal force on the weights increases and exerts an increasing force on the governor spring through toes on the weights.

When this force overcomes the force on the spring, the governor stem moves up till the force of the weight equals that of the spring. Motion of the stem is used to control fuel flow through a balanced relay valve designed so that the flow is straight through; when rotative speed is increased to the point where the stem is moved up, the valve is forced into the fuel path and restricts flow to the burner.

As the valve is forced into the fuel path, pressure is raised before the valve, this increase in pressure opening the relief valve to by-pass fuel not required. Both ends of the relay valve have spiral washout grooves to reduce pressure wedging and to clear out dirt which might cause the valve to stick.

To prevent rapid closing of the valve, with consequent governor instability, an orifice is installed in the leak-off line from the bottom of the relay, giving a dashpot action which prevents the valve from moving faster than the engine can respond.

A four-element pump provides pressure lubrication, one element for delivering oil to the bearings, and three for scavenging. The pump draws oil from the tank and pumps it through the filter, relief valve, cooler, bearings, and accessory gear case. A check valve is provided between the scavenge pump and tank so that the latter can, if necessary, be installed above the engine center line.

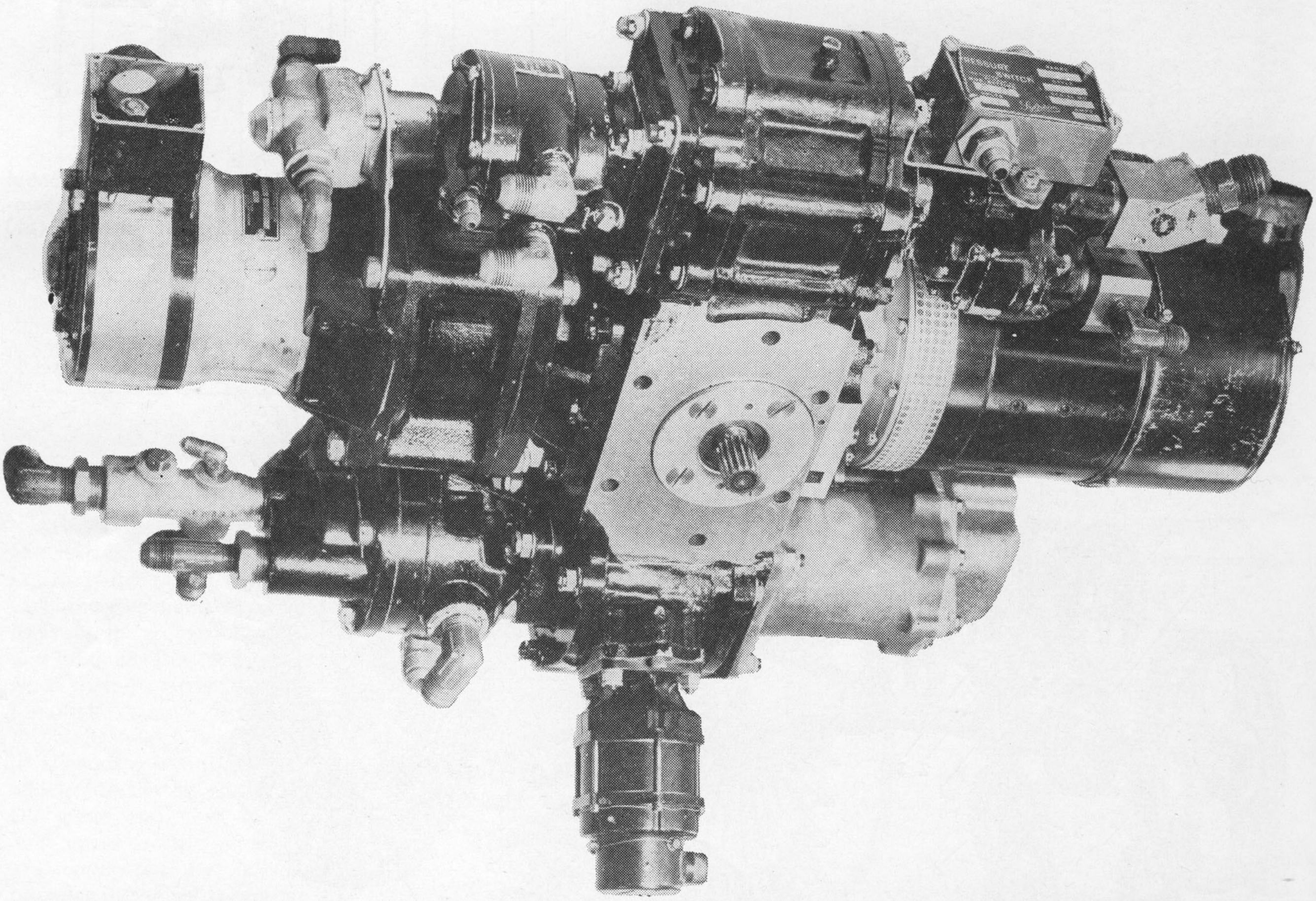


Fig. 1. Accessories of the 19-B (seen from below), with connection fitting on a splined drive in the middle of the gearbox mounting face. Accessories on the front face, top to bottom, include: hydraulic or vacuum pump, starter motor and lubricating-scavenger pump; on the side face, tachometer generator; on the rear face, fuel pump, generator, and governor.

General Electric I-16

The accessories for the GE I-16 turbojet are located in the front of the engine and consist of the starter, starting fuel pump, main fuel pump, governor, lube and scavenger pump, tachometer generator, the generator, the lube-oil filter, and relief valve (1).

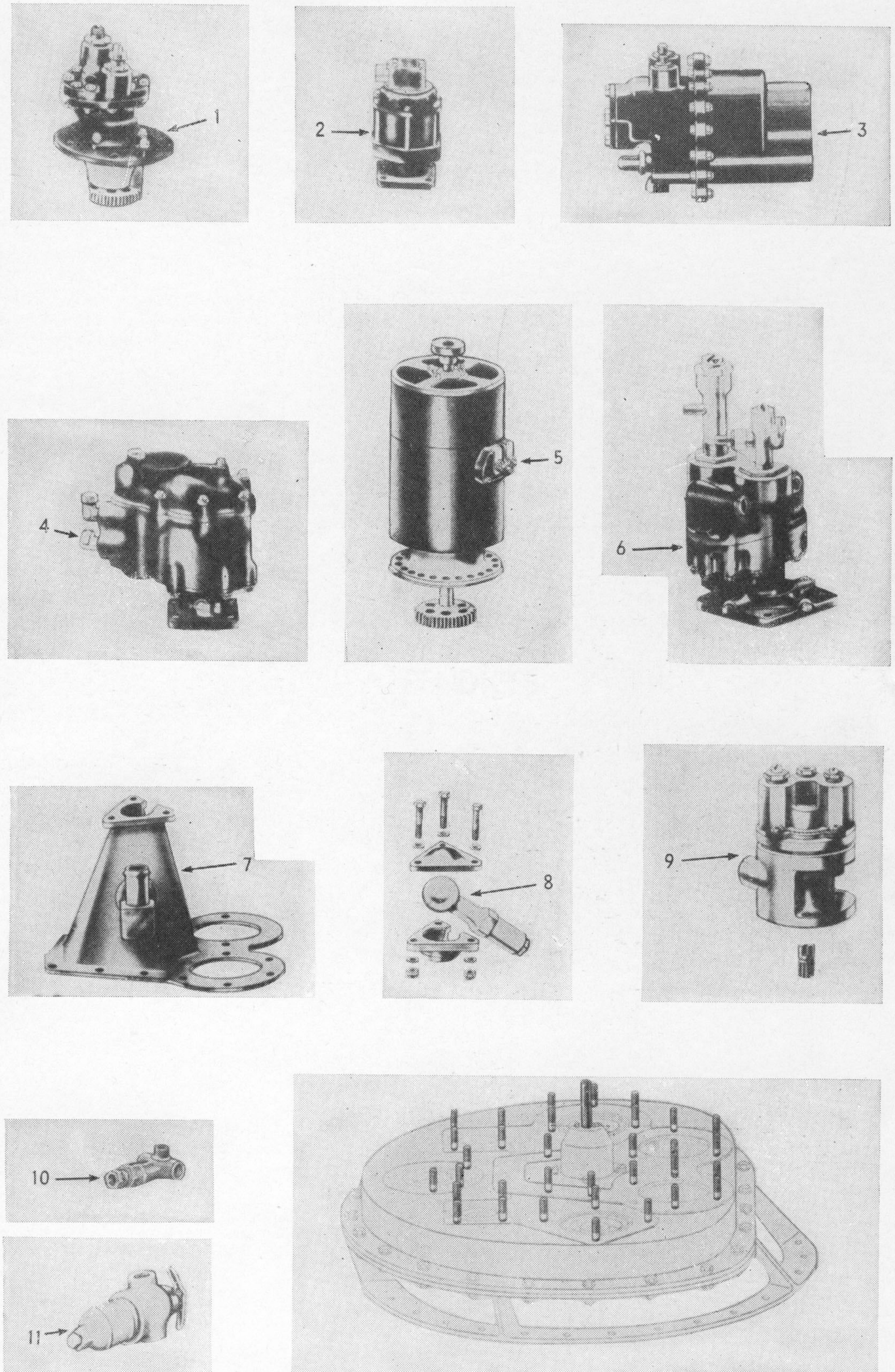


Fig. 1. The GE I-16 accessory components include (1) starting fuel pump; (2) tachometer generator; (3) barometric valve; (4) governor; (5) starter; (6) main fuel pump; (7) support housing; (8) ball support; (9) lube and scavenger pump; (10) lube relief valve; (11) lube-oil filter.

APPENDICES

SPECIFICATIONS OF U.S. AIR FORCE AND NAVY AIRCRAFT

Manufacturer	Designation: Model	Designation: Name	Type	Crew	Cargo or bomb load (lb.)	Powerplant: Number and make of engines	Powerplant: Max. hp. or lb. thrust ea.	Powerplant: At rpm	Powerplant: Normal rated hp. or lb. thrust ea.	Powerplant: At rpm	Powerplant: At altitude (ft.)	Fuel capacity (gal.)	Performance: Max. speed (mph.)	Performance: At altitude (ft.)	Performance: Service ceiling (ft.)	Performance: Rate of climb (fpm.)	Weights: Gross weight (lb.)	Weights: Empty weight (lb.)	Dimensions: Span	Dimensions: Length	Dimensions: Height	Current orders	Remarks
Beech Aircraft Corp. Wichita, Kans.	45	Mentor	Trainer	2	....	1 Con E-185-8	205	2600	....	......	......	50	180	SL	17,200	1000	2650	1901	32' 10"	25' 10.4"	9' 7"	......	Bch prop. 88" dia.
Boeing Airplane Co. Seattle, Wash	XB-47	Stratojet	Bomber	3	20,000+	*6 GE J-47-GE-11*	5200	......	*4800*	*7200*	......	....	600+	......	35,000+	*4000*	125,000+	*50,000*	116'	108'	....	*97*	Wichita plant producing B-47A.
	B-50D	Superfortress	Bomber	11	28,000	4 P & W R-4360	3500	......	*2650*	*2550*	*25,000*	*8000*	400+	......	35,000	*1800*	164,500	*80,000*	141' 3"	99'	34' 7"	*132*	C prop. 200" dia.
	C-97A	Stratofreighter	Transport	3-5	6100+[1]	4 P & W R-4360	3500	2700	2650	2550	25,000	7790	344	25,000	....	*1040*	150,000	73,518	141' 3"	110' 4"	38' 3"	50	HS prop. 200" dia.
	YL-15	Scout	Liaison	2	....	1 Lyc O-290-7	125	......	*125*	*2600*	*SL*	21	112	SL	16,400	628	2050	1509	40'	26' 2"	8' 8"	10[2]	Sensenich prop.
Chance Vought Aircraft Div. United Aircraft Corp. Dallas, Tex.	F4U-5	Corsair	Fighter	1	....	1 P & W R-2800-32W	2300	......	*1500*	*2600*	*30,000*	234[3]	470	*27,000*	42,500	4340	13,297	10,099	40' 11.7"	34' 6.2"	14' 9.5"	*120*	HS prop. 158" dia.
	F6U-1	Pirate	Fighter	1	....	1 We J-34-WE-30A	......	......	*3000*	*12,500*	......	700	550*	......	38,000+	7800	11,300	7560	32' 10"	37' 8"	12' 11"	*33*[25]	Afterburner fitted.
	F7U-1	Cutlass	Fighter	1	....	2 We J-34-WE-32	......	......	....	......	......	....	600*	......	....	*10,000*	*20,000*	*13,000*	....	....	....	......	Sweptwing carrier fighter.
Chase Aircraft Co. West Trenton, N. J.	YC-122C	....	Transport	2	1560[1]	2 Wr R-1820-101	1425	2700	1275	2500	......	1300	240	......	29,100	1340	40,000	19,000	95' 8"	61' 8"	24' 8"	*9*	C prop. 150" dia.
	XC-123	....	Transport	2	3570[1]	2 P & W R-2800-CB-14	2300	2700	1900	2500	......	1340	245	......	29,000	1250	54,000	26,000	110'	77' 1"	32' 8"	*1*	HS prop. 180" dia.
Consolidated Vultee Aircraft Corp. San Diego, Calif.	B-36D	....	Bomber	15[4]	10,000[5]	6 P & W R-4360-41[6]	3500	2700	*2650*	*2550*	*35,000*	21,000+	400+	......	40,000+	*1200*	*358,000*	*140,000*	230'	162'	46' 9"	170[7]	C prop. 228" dia.
	XC-99	....	Transport	10[8]	13,830[1]	6 P & W R-4360-25	3000	2700	*2500*	*2550*	*8500*	21,116	300+	......	30,000	*600*	265,000	135,000	230'	182' 6"	57' 6"	1	C prop. 228" dia.
	XF-92A	....	Fighter	1	....	1 Al J-33-A-23	5400	11,750	3900	11,250	SL	295	*725*	*50,000*	*60,000*	*12,000*	*13,000*	6000	31' 4"	41' 4"	11' 8.3"	1	60% delta swept wing.
	L-13	....	Liaison	3	....	1 Airc O-425-9	245	3200	240	3200	SL	112.5	115	SL	15,000	1050	2900	2070	40' 5.5"	31' 9"	8' 5"	300	Bch prop. 102" dia.
	XP5Y-1	....	Patrol	11	....	4 Al XT-40-A-4	5100	14,300	4500	14,300	SL	8700	*392*	*25,000*	*38,000*	*3000*	*140,000*	*80,000*	*145'*	*130'*	*45'*	2	AP prop. 180" dia.
	T-29A	....	Trainer	3	....	2 P & W R-2800-97	2400	2300	1800	2600	6000	1000	304	14,500	26,000	1470	40,500	29,000	91' 9"	74' 8"	26' 11"	48	HS prop. 157" dia.
Douglas Aircraft Co., Inc. Santa Monica, Calif.	C-124A	Globemaster 2	Transport	5	50,000	4 P & W R-4360-20W	3500	2700	2650	2550	7500	11,100	*295*	*10,000*	*22,800*	*790*	175,000	95,707	173' 3"	127' 2"	48' 3"	*66*	C prop. 198" dia.
	AD-2	Skyraider	Attack	1	10,000	1 Wr R-3350-26W	2700	......	*2300*	*2600*	*6200*	*390*	*360*	*3500*	*2500*	*1600*	16,065	10,519	50' .18'	38' 10"	15' 7"	*356*	18 versions built.
	F3D-1	Skyknight	Fighter	2	....	*2 We J-34-WE-38*	......	......	*3600*	*12,500*	......	....	*562*	*30,000*	....	....	*20,000*	*11,750*	*50'*	*45'*	16'	*30*	Long-range carrier fighter.
Fairchild E. & A. Corp. Aircraft Div. Hagerstown, Md.	C-82-A	Packet	Transport	5	2312[1]	2 P & W R-2800-85	2100	2800	1700	2600	7300	2614	239[9]	17,500	20,000	800	54,000	31,288	106.5'	77.08'	26.34'	220[10]	HS prop. 182" dia.
	C-119(R4Q)	Packet	Transport	5	2700[1]	2 P & W R-4360-20W	3500	2700	2650	2550	6000	2798	265	18,000	21,200	1130	71,800	38,329	109' 3"	85' 5"	26' 6"	204[2]	HS prop. 180" dia.
	XC-120	....	Transport	5	2700[1]	2 P & W R-4360-20	3250	2800	2650	2550	6000	2798	245	18,000	23,700	1100	64,000	38,174	109' 3"	82' 10"	25' 1"	1[2]	HS prop. 181" dia.
Grumman Aircraft Engineering Corp. Bethpage, L. I.	AF-2	....	Attack	3	....	*1 P & W R-2800-34W*	2100	......	....	......	......	....	......	......	....	....	*22,400*	*16,000*	....	....	....	*23*	HS prop.
	F9F-3	Panther	Fighter	1	....	1 Al J-33-A	5000	......	....	......	......	....	600+	......	....	....	*16,000*	*8600*	....	....	....	*417*	F9F-5 has P & W J-48.
	SA-16A	....	Rescue	6	....	2 Wr R-1820-76	1400	......	1275	......	......	*1200*	270	*15,000*	....	*1600*	*26,000*	*16,000*	80'	61' 4"	24' 5"	58[2]	HS prop.
Lockheed Aircraft Corp. Burbank, Calif.	C-121A	Constellation	Transport	5[11]	2844[1]	4 Wr 749C18BD1	2500	2800	2100	2400	4400	5820	354	23,000	....	1280	105,000	58,500	123'	95' 3"	18' 9"	10	C prop. Max range is 5200 mi.
	F-80(TO-1)	Shooting Star	Fighter	1	....	1 Al J-33-A-23	5400[12]	11,750	....	......	......	755	600	......	45,000+	5100	15,336	8215	38' 10"	34' 6"	11' 4"	1727[2]	Takeoff over 50 ft. obstacle, 4370 ft.

	XF-90	...	Fighter	1	...	*2 We J-46-WE-3*	*6000*	...	...	...	...	...	*M1.5*	...	...	...	26,000*	...	40'*	56'*	15'*	*2*	USAF penetration fighter.
	F-94A	...	Fighter	2	...	1 Al 400-D9	6000	...	...	...	...	648	600+	...	...	...	15,710	9638	38' 10"	40' 1.5"	12' 8"	110[2]	Takeoff over 50' obstacle, 3720 ft.
	P2V	Neptune	Patrol	7	...	2 Wr C18BA1	3200	2900	2300	2600	6200	2821	320	9400	22,300	*1050*	58,000	34,000	100'	77' 10"	28' 1"	278[2]	Takeoff over 50' obstacle, 3120 ft.
	XR60-1	Constitution	Transport	12	6870[1]	4 P & W R-4360-22W	3500	2700	2650	2550	23,500	8250	303	20,000	*28,000*	722	184,000	116,275	189' 1"	156' 1"	50' 4"	0	C prop. 200" dia.
	T-33(TO-2)	...	Trainer	2	...	1 Al J-33-A-23	5400	11,750	*4600*	*11,750*	...	683	600	*27,000*	...	5250	14,442	8084	38' 10"	37' 8"	11' 8"	156	Takeoff over 50' obstacle, 3830 ft.
Glenn L. Martin Co. Baltimore, Md.	AM-1	Mauler	Attack	1	7800	1 P & W R-4360-4	*3250*	*2700*	2500	...	...	*950+*	350+	...	*27,500*	2500+	22,166[13]	15,000*	50' 1"	41' 6"	16' 11"	149[2]	C prop. 176" dia.
	XB-51	...	Bomber	2	...	*3 GE J-47-GE-9*	...	...	*5400*	*7700*	...	*4000*	*585*	*25,000*	*45,000*	*6000*	*45,000*	*22,000*	55'	80'	17'	...	Ground attack type.
	JRM-2	Mars	Transport	11	...	4 P & W R-4360-4	3000	...	2500	*2700*	*5600*	13,220	238	*13,500*	17,670	652	165,000	80,311	200'	120' 3"	44' 7"	1[14]	C prop. 200" dia.
	PBM-5A	Mariner	Patrol	9	...	2 P & W R-2800	2100	...	1700	*2800*	*5500*	3000+	180+	...	15,000+	370+	60,300	39,698	118'	80'	27' 6"	36	C prop. Amphibian patrol bomber.
	P4M-1	Mercator	Patrol	9	...	*2 P & W R-4360-20*[15]	...	...	3250	*2700*	*5000*	*4200*	*395*	*15,000*	*30,000*	*2500*	80,000+	...	114'	85'	...	19[2]	Range 3000 mi. plus.
	P5M-1	...	Patrol	...	...	*2 Wr R-3350-26W*	...	...	*2700*	*2900*	*SL*	...	*270*	...	...	...	...	*36,000*	...	...	...	*5*	New type hull.
McDonnell Aircraft Corp. St. Louis, Mo.	XF-88	...	Fighter	1	...	*2 We J-34-WE-22*	*3600*[23]	...	...	...	...	*1400*	*730*	*SL*	*40,000*	*6000*	*27,000*	*12,000*	39' 8"	54' 1.4"	17' 3.2"	2	Range 1725 mi.
	FH-1	Phantom	Fighter	1	...	2 We J-30-WE-20	1600	...	...	...	...	*375+*	450+	SL	35,000+	4000+	12,000	*6700*	41'	39'	14'	60[2]	No wind SL takeoff 1165 ft.
	F2H-2	Banshee	Fighter	1	...	2 We J-34-WE-34	...	...	*3200*	*12,500*	*SL*	5000+	575+	SL	50,000+	9000+	19,000	*8400*	41' 6"	40'	14' 6"	179[16]	Normal range 2000 mi. plus with tip tanks
North American Aviation, Inc. Los Angeles, Calif.	AJ-1	...	Attack	3	...	*2 P & W R-2800-34W*[17]	*2300*	*2800*	...	...	...	...	...	...	...	...	*55,000*	*27,500*	...	...	...	*55*	HS prop. Can carry atomic bomb.
	B-45	Tornado	Bomber	4	20,000+	*4 GE J-47-GE-3*	5200[12]	...	*4850*	*7700*	...	*4500*	550*	...	40,000+	*2500*	82,600	*27,000*	89' 6"	74'	25'	139[2]	Tactical radius 800 mi. plus.
	F-86A	Sabre	Fighter	1	...	*1 GE J-47-GE-9*	5200	*7700*	...	...	...	*430+*	*720*	*SL*	40,000+	*6500*	*18,000*	*10,000*	37'	37'	14'	554[2]	Tactical radius 500 mi. plus.
	YF-93A	...	Fighter	1	...	1 P & W J-48-P-6	*8000**[23]	...	...	...	...	...	...	...	*50,000*	...	20,000	*12,000*	39'	44'	16'	...	Flush intakes.
	T-28	...	Trainer	2	...	1 Wr R-1300-1	800	...	700	...	...	125	288	5900	29,800	2570	6365	5111	40.1'	32'	12. 6'	268[2]	AP prop. 125" dia.
Northrop Aircraft, Inc. Hawthorne, Calif.	YRB-49A	Flying Wing	Bomber	5	...	6 Al J-35-19	5000	...	...	...	...	...	...	...	...	...	213,000	...	172'	53'	15'	1[2]	Turbojet version of B-35.
	C-125	Raider	Transport	2	2290[1]	3 Wr R-1820-99	1200	2500	1000	2300	SL[18]	...	201	5200	15,200[19]	1155	38,000	...	86'	67'	23'	23[2]	C prop. 145" dia.
	F 89A	Scorpion	Fighter	2	...	2 Al J-35[20]	...	...	*4900*	*7700*	...	...	600*	...	40,000*	*5000*	30,000+	*19,000*	50'*	50'*	15'*	*48*	All-weather fighter.
Republic Aviation Corp. Farmingdale, N. Y.	F-84E	Thunderjet	Fighter	1	4500*	1 Al J-35-A-17	5000	7800	*4900*	*7700*	...	*960*	630*	SL	*47,500*	*4600*	*22,000*	10,000	37'	38'+	12'+	1000[21]	Some other model F-84's with ANG.
	XF-91	...	Fighter	1	...	1 GE J-47[22]	*6400*[23]	...	...	...	...	...	*M1*	...	...	*15,000*	...	*12,000*	30'	49'	...	2	Interceptor with inverse taper wings.
	XR-12	...	Reconn	7	...	4 P & W R-4360-31	3000	2700	...	...	...	5000+	470	40,000	44,000+	1600	101,400	*65,000*	93'	129'	28'	2[2]	C prop. 194" dia.
Ryan Aeronautical Co. San Diego, Calif.	L-17B	Navion	Liaison	1[24]	20[1]	1 Con E-185-3	205	2600	185	2300	SL	60.5	157	SL	15,600	830	2750	1838	33' 4.5"	27' 3"	8' 7.6"	163[2]	H prop. 84" dia.
Texas Engineering & Mfg. Dallas, Tex.	T-35	...	Trainer	2	...	1 Con C-145-2H	145	2700	145	2700	...	28.5	145	SL	14,000	925	1900	1280	29.3'	21.6'	6.3'	...	Aer prop. 74" dia.

Italics: Aviation Week estimates.

* Approximate.
Aer—Aeromatic.
AP—Aeroproducts.
Airc—Aircooled Motors.
Al—Allison.
Bch—Beech.
C—Curtiss.
Con—Continental.
GE—General Electric.
H—Hartzell.
HS—Hamilton Standard.
Lyc—Lycoming.
P&W—Pratt & Whitney.
SL—Sea Level.
We—Westinghouse.
Wr—Wright.

1 Cubic feet.
2 Total ordered.
3 Internal.
4 Includes four relief members.
5 Maximum bomb load is 84,000 lb.
6 Plus four GE J-47 turbojets at 5200 lb. thrust.
7 Total ordered all models.
8 Includes five relief members.
9 At normal rated hp.
10 Total ordered, contracts completed.
11 Plus 48 passengers.
12 Wet.
13 Maximum weight is 29,000 lb.
14 Plus four JRM-1, similar but with Wr R-3350-8 engines of 2400 takeoff hp. each.
15 Plus two Allison J-33A-23 at 4000 lb. thrust each at 11,750 rpm.
16 179 with tip tanks, including 14 night fighters.
17 Plus one Allison J-33A—12 turbojet of 5600 lb. thrust at 11,750 rpm.
18 Sea level to 5200 ft.
19 At 36,000 lb. gross weight.
20 In prototype, production-plane engines not released.
21 All models: 700 in service Jan. 1, 1950.
22 Plus four auxiliary rocket motors in tail.
23 With afterburner.
24 Plus three passengers.
25 Number completed.

SPECIFICATIONS OF U.S. PERSONAL AND EXECUTIVE AIRCRAFT

Manufacturer	Designation	Number of Places	POWER PLANT: Number, make and hp. of engine	POWER PLANT: Make of propeller	POWER PLANT: Diameter, in.	PERFORMANCE: High speed (mph.)	PERFORMANCE: Cruising speed (mph.)	PERFORMANCE: Landing speed (mph.)	PERFORMANCE: Takeoff distance [1] (ft.)	PERFORMANCE: Landing distance [2] (ft.)	PERFORMANCE: S. L. rate of climb first min. (fpm.)	PERFORMANCE: Normal range (mi.) [3]	WEIGHTS: Gross weight (lb.)	WEIGHTS: Empty weight (lb.)	DIMENSIONS: Span	DIMENSIONS: Length	DIMENSIONS: Height	EQUIPMENT: Instruments (type & make) [4]	EQUIPMENT: Radio	EQUIPMENT: Position lights	EQUIPMENT: Landing lights	EQUIPMENT: Starter	Price, F. A. F.
Aerocar, Inc. Longview, Wash.	1[5]	2	Airc 4A4 100-B3@100	Sen	74	110+	100+	53	1225	800	500+	300+	1750	1252	30'	21'	7' 2"	1AP, 2USG; 3USG; 6AC[6]	. . .	. .	. .	DR	$8000*
Aero Design & Engineering Corp. Culver City, Calif.	Aero Commander	5-7	2 Lyc 0-435-A@190	. . . .	82-85	190	180	57	1000	850	1250	1000	4600	2800	43'	32'	12'	. . . .	GE	Gr	. .	DR	30,000*
Aero-Flight Aircraft Corp. Long Beach, Calif.	Streak 85	2	1 Con C-85@92	Sen	68	175	165	56	812	860	950	750	1400	850	25' 3"	21' 2"	8' 3"	. . . .	H	Gr	GE	DR	. . . . . .
	Streak 125	2	1 Con C-125@135	Sen	70	202	192	59	702	915	1500	850	1560	955	25' 3"	22' 4"	8' 3"	. . . .	H	Gr	GE	DR	. . . . . .
Aeronca Aircraft Corp. Middletown, Ohio	Champion 7EC[7]	2	1 Con C-90-12F@90	Sen	72	110	100	44	906	1342	800	351	1450	890	35' 2"	21' 8"	7'	2USG; 3USG; 4SW; 5SW; 6AC; 12SW	Be	Gr	Gr	DR	2695
	Champion 7CCM	2	1 Con C-90-12@90	Sen	. . .	110	100	42	850	1250	825	. . . .	1300	809	35' 2"	21' 6"	7'	2USG; 3USG; 4SW; 5SW; 6AC	. . .	Gr	. .	. .	2545
	Sedan 15 AC	4	1 Con C-145@145	Sen	. . .	129	114	53	1000	1600	800	456	2050	1150	37' 6"	25' 3"	7'	2USG; 3USG; 4SW; 5SW; 6AC; 12SW	. . .	Gr	GE	DR	4848
All American Aircraft, Inc. Long Beach, Calif.	Ensign 10 A	2	1 Con C-85@85	McC	74	120	100	55	750	500	700	400	1550	1000	33'	22'	9'	1,2,3P; 4,5,6,7,11, 12SW	Air	Gr	. .	DR	3495
Anderson, Greenwood & Co. Houston, Tex.	AG-14[8]	2	1 Con C-90@95	Har	72	120+	110+	. . . .	. . . .	. . .	700+	400	1400	850	34'	22' 6"	7' 6"	1AP; 2USG; 3K; 4,5, 6,7AC	. . .	Gr	. .	DR	. . . . . .
Aquaflight, Inc. Wilmington, Del.	Aqua 2	6	2 Lyc 0-435A@190	Aer	78	170	150	55	1050	850	1000	800	4050	2600	36' 6"	29' 6"	12'	2,3,6,9,10,16,17,18, 21 all SW	Be	Gr	GE	DR	25,000
Baumann Aircraft Corp. Glendale, Calif.	Brigadier B-290	5	2 Con C-145-2 H@290	Sen	72	175	150	57	1100	500	1360	750	3500	2200	40'	28' 1"	10' 6"	. . . .	Be	. .	. .	DR	22,500
Beech Aircraft Corp. Wichita, Kan.	Bonanza A35	4	1 Con E-185-8@185	Bch	88	184	170	56[9]	1435	850	890	750	2650	1575	32' 10"	25' 2"	6' 6½"	1AP, 2K, 8K, 6AC, 9K 10Sc, 16K, 19E, 22[10]	. . .	Gr	GE	DR	10,975
	Bonanza B35	4	1 Con E-185-8@196	Bch	88	184	170	56[9]	. . . .	. . .	. . . .	750	2650	1575	32' 10"	25' 2"	6' 6½"	1AP; 2K; 8K; 6AC; 9K 10Sc; 16K; 19E; 22B[10]					
	Twin Bonanza 50[11]	5-6	2 Lyc GO-435@260	Bch	. . .	. . . .	180+	. . . .	. . . .	. . .	. . . .	1000*	. . . .	. . .	. . . .	. . . .	. . . . .		RCA	Gr	GE	Ec	. . . . . .
Bellanca Aircraft Corp. New Castle, Del.	Cruisemaster 14-19	4	1 Lyc 0-435A@190	Har[12]	78	187	180	43	. . . .	. . .	1400	680	2600	1525	34' 1"	23'	6' 2"	1AP; 2K-P; 8K-P; 6SW; 7SW; 9K-P; 12SW[13] 10K-P.	Avi	Gr	GE	DR	9500
	Cruisair 14-13-3 Sr.	4	1 Airc 6A4-150-B3@150	Aer[15]	74	169	150	45	506	437	1100	. . . .	2150	1255	34' 2"	21' 3"	6' 2½"	1AP; 2K; 6SW; 7SW; 9K-P; 8K-P; 10K; 12SW[14]; 19E.	GE	Gr	GE	DR	. . . . . .
Cal-Aero Technical Institute Glendale, Calif.	XLC-1	1	1 CAX1000[16]@128	None	. . .	250	200	60[9]	. . . .	. . .	1380	325	1275	585	20' 10"	17' 11"	5' 11"	. . . .	. . .	. .	. .	. .	. . . . . .
Callair Afton, Wy.	Callair A-2 & A-3	2-3	1 Con or Lyc@125	Sen	76	120	109	45[9]	. . . .	. . .	1000	456	1550	975	35' 9½"	23' 5½"	7'	. . . .	. . .	Gr	Gr	Ec	4525
Cessna Aircraft Co. Wichita, Kan.	140	2	1 Con C-85 or 90@90hp.	Sen	74	125+[17]	105+[18]	41[9]	1645[19]	1530	640[20]	450	1500	900	33' 4"	21' 6"	6' 3¼"	. . . .	. . .	. .	. .	. .	. . . . . .
	170	4	1 Con C-145@145	Sen	73	140+	120+	55[9]	1820	1755	690	450	2200	1200	36'	25'	6' 7½"	. . . .	. . .	. .	. .	. .	. . . . . .
	190	4-5	1 Con W-670-23@240	Ham	93	170	160	62.5[9]	1670	1495	1050	700+	3350	2050	36' 2"	27' 4"	7' 2"	. . . .	. . .	. .	. .	. .	. . . . . .
	195	4-5	1 Jac R755-A2@300	Ham	93	180	165	62.5[9]	1500	1495	1200	700+	3350	2060	36' 2"	27' 4"	7' 2"	. . . .	. . .	. .	. .	. .	. . . . . .
Colonial Aircraft Corp. Huntington Sta., L. I., N. Y.	Skimmer C-1	2-3	1 Lyc 0-290D@130	Aer	73	125	115	50	. . . .	. . .	700	700	1950	1300	34'	23' 6"	8' 10"	1,2,4,5,6,7,8,9,10, 14, 19, 23.	Na	Gr	. .	DR	9750
Continental, Inc. Danbury, Conn.	Airphibian	2[21]	1	Sen	. . .	120	110	48	. . . .	. . .	600	. . . .	. . .	. . .	. . . .	. . . .	. . . . .	1,2,3,4,5,6,7,10,12, 19.	. . .	. .	. .	. .	. . . . . .
Emigh Trojan Aircraft Douglas, Ariz.	Trojan A-2[22]	2	1 Con C-90-12F@90	McC	. . .	125	115	48	1460	1460	800	600	1450	874	31' 10"	20' 5"	6' 5"	1,2,3K; 4,5,6,11, 12SW; 24.	. . .	. .	. .	DR	3295
Funk Aircraft Co. Coffeeville, Kan.	B85C[23]	2	1 Con C-85 or C-90@85	Lew	72	115	105	40	400	400	800	400	1350	890	35'	20' 1"	6' 1"	1AP; 2,3K; 4 5W, 6, 7AC, 4SW;	. . .	Gr	. .	DR	3895

Jamieson Aircraft Co., Inc. DeLand, Fla.	Jupiter J-2-L1	3	1 Lyc 0-235-C1@115	. . .	74	167	150	–40	400	400	1050	700	1600	800	29'	20' 10"	6' 9"	1K;2,3;4,5,6,7,11,12, 22SW	. . .	. .	. .	DR	2500
Johnson Aircraft Corp. Tyler, Tex.	Bullet 185	4	1 Con E-185-1@205	Har	78	190	175	58[9]	1250	. . .	800	800	2300	1300	28'	23' 1"	8' 3"	1,2,3,4,5,6,7,10,11, 12,15,16,19,25	Be	Gr	GE	DR	4995
Mooney Aircraft, Inc. Wichita, Kan.	M-18L[25]	1	1 Lyc 0-145-B2@65	Sen[24]	60	138	115	43	1000	1200	1090	390	780	500	26.8'	17.6'	6.2'	1K; 2, 3USG; 4,5,6SW	. . .	. .	. .	. .	2250
Morrisey Aircraft Co. Long Beach, Calif.	Nifty 1000C	2	1 Con C-90-12F@95	Sen	72	122	110	40	280	310	850	325	1350	830	29'	20'	7' 2"	. . . .	. . .	. .	. .	. .	2900*
Piper Aircraft Corp. Lock Haven, Pa.	Super Cub 95 (PA-18)[26]	2	1 Con C-90@90	. . .	74	112	100	42[27]	1151	. . .	700	360	1500	790	35.3'	22.4'	6.7'	. . . .	. . .	. .	. .	. .	. . . . .
	Super Cub 105 (PA-18)[26]	2	1 Lyc 108@108	. . .	74	117	105	36[27]	960	. . .	850	360	1500	825	35.3'	22.4'	6.7'	. . . .	. . .	. .	. .	. .	. . . . .
	Pacer 115 (PA-20)[26]	4	1 Lyc 0-235-C1@108	. . .	74	125	112	50[27]	. . . .	. . .	600	580	1750	920	29.3'	20.4'	6' 2½"	. . . .	. . .	. .	. .	. .	. . . . .
	Pacer 125 (PA-20)[26]	4	1 Lyc 0-290-D@125	. . .	74	135	125	48[27]	. . . .	. . .	810	580	1800	970	29.3'	20.4'	6' 2½"	. . . .	. . .	. .	. .	. .	. . . . .
	Pacer 135 (PA-20)	4	1 Lyc 0-290-D@125	Aer	74	135	134[28]	48	. . . .	. . .	850	625	1800	990	29.3'	20.4'	6' 2½"	. . . .	. . .	. .	. .	. .	. . . . .
Ryan Aeronautical Co. San Diego, Calif.	Navion Utility 205	4	1 Con E-185-3@205	Aer	85	157	150	54	875	875	830	500	2750	1721	33' 4½"	27' 3"	8' 7-5/8"	1AP; 2USG; 3; 4,5, 6SW; 7KS; 11,12SW; 16USG.	RCA	Gr	. .	DR	9485
	Navion De Luxe 205	4	1 Con E-185-3@205	Har	84	163	155	54	875	875	900	500	2750	1782	33' 4½"	27' 3"	8' 7-5/8"	1AP; 2USG; 8K; 4,5, 6SW; 7KS; 9; 10Sc; 11, 12SW[29]	RCA	Gr	Gr	DR	10,985
	Navion Super 260	4	1 Lyc GO-435-C2@260	Kop	93	174	170	55	770	875	1250	640	2850	1897	33' 4½"	27' 6"	8' 7-5/8"	1AP; 2USG; 8K; 4,5, 6SW; 7KS; 9; 10Sc; 11, 12SW,[30]	RCA	Gr	Gr	Ec	13,985
Sanders Aviation, Inc. – Engineering & Research Corp. Riverdale, Md.	Ercoupe G[31]	2½	1 Con C-85@85	Sen	74	125	110	48	1850	800	560	530	1400	838	30'	30' 3"	5' 6"	1AP; 3AM; 4, 5, 6, 12SW.	Le	Gr	. .	DR	3995
Schroeder Aircraft Rochester, N. Y.	Dragontail CX-200-L6	1	1 Con C-85FJ@87	Sen	58	220[32]	180[32]	60	. . . .	. . .	1500*	450	820	570	20' 4"	18'	3' 6"	. . . .	. . .	. .	. .	. .	. . . . .
Spratt Aircraft Co. Deep River, Conn.	8[33]	2	1 Lyc 0-145@75	Sen	60	105	95	52[9]	. . . .	. . .	900	250	1000	520	20'	16'	5'	2, 4, 5	. . .	. .	. .	. .	1500*
Taylorcraft, Inc. Conway, Pa.	Special De Luxe	2	1 Con C-65@65	. . .	72	105	95	38[9]	. . . .	. . .	600	350	1200	750	36'	21'	6' 6"	. . . .	. . .	. .	. .	. .	2195
	Turist	4	1 Con C-145@145	. . .	. . .	125	115	36[9]	. . . .	. . .	700	. . .	2200	1220	36' 4"	24'	7' 1"	. . . .	. . .	Gr	. .	. .	4895
	Sportsman	2	1 Con C-85-12@85	. . .	72	120	110	38	. . . .	. . .	700	300	1280	850	36'	22'	6' 6"	. . . .	. . .	Gr	. .	DR	2950
Texas Engineering & Manufacturing Co., Inc. Dallas, Tex.	Swift 125 GC-1B	2	1 Con C-125-2@125	Aer	73	150	140	48	. . . .	. . .	1000	425	1710	1185	29' 2"	20' 10¾"	6' 1"	2, 3K; 4, 5AC; 6K; 11AC.	GE	Gr	. .	DR	4495

*–approximate
AC–A. C. Spark Plug
AM–Aero-Marine
Aero–Aeromatic
Air–Airadio
Airc–Aircooled
AP–Airpath
Avi–Avigator
Bch–Beech
Be–Bendix
Con–Continental
DR–Delco-Remy
E–Elgin
Ec–Eclipse
F.A.F.–Fly-Away-Factory
GE–General Electric
Gr–Grimes
H–Hallicrafter
Ham–Hamilton Standard
Har–Hartzell
J–Jacobs
K–Kollsman
K-P–Kollsman or Pioneer
KS–King-Seeley
Kop–Koppers
Le–Lear
Lew–Lewis
Lyc–Lycoming
McC–McCauley
Na–Narco
RCA–Radio Corp. of America
Sc–Schwien
Sen–Sensenich
SW–Stewart-Warner
USG–U. S. Gauge

1–compass, 2–airspeed, 3–altimeter, 4–oil pressure, 5–oil temp, 6–tach, 7–fuel gage, 8–sensitive altimeter, 9–rate of climb, 10–turn and bank, 11–fuel pressure, 12–ammeter, 13–voltmeter, 14–stall warning, 15–landing gear indicator, 16–manifold pressure, 17–artificial horizon, 18–directional gyro, 19–clock, 20–cylinder-head temp, 21–3-in1 engine group, 22–engine gage cluster unit, 23–suction gage, 24–emergency fuel pump, 25–vertical speed indicator, 26–outside air temp.

1–No wind S.L. takeoff at gross weight over 50-ft. obstacle.
2–No wind S.L. landing over 50-ft. obstacle.
3–Fully loaded and without auxiliary fuel provisions.
4–Numeral indicates instrument type, letters indicate maker–see listings at bottom of tables.
5–Plane-car. Made to order only. Production version will have Lyc O-290-D engine rated at 125 hp. at 2600 rpm., fuel capacity 24 gal., fuel consumption 7 gal./hr.
6–Also comes with AC hourmeter, speedometer, odemeter and engine instruments by SW, DR windshield wiper, horn, Sparks Worthington.
7–Has electrical system with battery, 12-v generator, starter, wiring for landing, navigation and instrument lights.
8–Components for five units being produced.
9–Stalling speed.
10–Beech engine gage cluster unit with AC fuel pressure, fuel quantity, oil temp, oil pressure, ammeter, and MB cylinder head temp gage.
11–Further specs will not be available until completion of flight test program.
12–Or Aeromatic with altitude control.
13–Also Kollsman manifold pressure gage. Elgin clock, Lewis Engrg. cylinder head temp, U. S. 3-in-1 gage.
14–Also Elgin clock and U. S. Instrument 3-in-one gage.
15–Or Sensenich.
16–Turbojet unit still under development.
17–For C-90; 120 mph. with C-85.
18–Over 100 mph. with C-85
19–1850 ft. with C-85.
20–555 fpm. with C-85.
21–Seating as car can be increased to 4.
22–Ten sold in 1949.
23–Made to order.
24–Or Flottorp–prop diameters 60-66 in.
25–73 sold in 1949.
26–Performance figures are with plane fitted with slowest turning fixed pitch prop, at gross load and under standard conditions.
27–With flaps.
28–At 5000 ft. at 75 percent power.
29–And U. S. Gauge manifold pressure, Elgin clock, cylinder-head temp, and Scott outside air temp.
30–Also Elgin clock, U. S. Gauge manifold pressure, Scott outside air temp. and cylinder head temp gage.
31–53 sold in 1949.
32–Design speeds.
33–Controllable wing flying boat.

SPECIFICATIONS OF LEADING CANADIAN, BRITISH, AND FRENCH PLANES

Manufacturer	Designation	Category	Number of crew (or places)	Number of passengers	POWER PLANT: Number and make of engines	Normal rated hp. ea.	At rpm.	PERFORMANCE: Cruising speed (mph.)	At altitude (ft.)	S. L. climb at gross weight (fpm.)	Normal range (mi.)	Service ceiling (ft.)	WEIGHTS: Gross weight (lb.)	Empty weight (lb.)	DIMENSIONS: Span	Length	Height	Top speed (mph.)	At altitude (ft.)	Remarks
CANADA																				
A. V. Roe Canada, Ltd.	C-102 Jetliner	Transport	4	40-60	4R-R Derwent 5	3600[1]	14,700	465	30,000	2770	600	....	65,000	33,400	98' 1"	82' 9"	26' 5.5"	500+	30,000	Basic price $700,000
	CF-100	Fighter	2	...	2 R-R Avon	7500[1]*	....	...	....	...	...	....	.....	.....	....	.....	.....	...	....	Prototype being tested
Canadair, Ltd.	C-4	Transport	4	36-55	4 R-R Merlin 626	1500	2850	325[3]	25,200	1100	3880[2]	....	82,000	46,807	117.5'	93.62'	27.53'	329	20,600	Cargo capacity 698 cu. ft
Canadian Car & Foundry Co., Ltd.	N-29 Norseman 5	Transport	1-2	8-9	1 P&W R-1340 AN-1	550	2250	141[3]	5000	700	464	....	7400[3]	4250[3]	51' 8"	32' 4"	10' 1"	155[3]	5000	Basic price $31,900 less engine
de Havilland Aircraft of Canada, Ltd.	DHC-1 Chipmunk	Trainer	2	...	1 DH Gipsy 1C	130	2100	134	5000	900	485	17,200	1930	1184	34' 4"	25' 5"	7'	140	2400	Basic price $10,150
	DHC-2 Beaver	Transport	1	6	1 P&W R-985 AN-6B	400	2200	153	5000	1290	578	26,000	4650	2775	48'	30' 3"	10' 7"	171	S. L.	Basic price $26,450 in U. S.
GREAT BRITAIN																				
Airspeed, Ltd.	AS-57 Ambassador	Transport	4-5	40-50	2 Br Centaurus 661	2313	2,500	280	20,000	1600	850[4]	....	52,000	34,650	115'	81.3'	18.25'	312	21,500	$320,000 basic; 20 on order
Armstrong Whitworth Aircraft, Ltd.	AW-55 Apollo	Transport	3-4	24-40	4 AS Mamba 1	659[5]	14,000	276	20,000	1500	1100	....	45,000	28,750	92'	72'	26'	345	20,000	Approx. $360,000 equipped; 2 on order
A. V. Roe & Co., Ltd.	701 Athena T.2	Trainer	2	...	1 R-R Merlin 35	1060	2650	277	10,000	1830	640	29,700	8132	6542	40'	37' 6"	13'	300	10,000	....
	707	Research	1	...	1 R-R Derwent	...	....	....	....	...	....	....	.....	.....	33'	30'	11' 3"	...	....	Swept wing high-speed research
Auster Aircraft, Ltd.	Autocrat J/1	Personal	3	...	1 B1 Cirrus Minor 2	100	....	92	....	500	320	15,300	1700	1052	36'	23' 5"	.....	110	....	$3776; dual controls, flaps
	Aiglet J/1B	Personal	3	...	1 DH Gipsy Major 1	130	....	100	....	900	220	18,000	1850	1180	36'	23' 4"	.....	128	....	$3160
	Arrow J/2	Personal	2	...	1 Con	75	....	80	....	500	320	10,000	1400	872	36'	22' 11"	.....	98	....	$2660 for export
	J/4	Personal	2	...	1 B1 Cirrus Minor 1	90	....	86[6]	....	700	320	12,500	1400	957	36'	23' 6"	.....	110	....	$3300
	J/5	Personal	3	...	1 DH Gipsy Major 1	130	....	98[6]	....	600	390	12,000	1850	1186	36'	23' 2"	.....	120[6]	....	$3920; flaps
	Autocar J/5B	Personal	4	...	1 DH Gipsy Major 1	130	....	98	....	620	500	13,500	2100	1305	36'	23' 4"	.....	115	....	$4410; latest model
	Avis 1	Personal	4	...	1 DH Gipsy Major 10	145	....	90	....	510	520	10,000	2550	1480	36' 4"	23' 6"	.....	113	....	
	Avis 2	Personal	4	...	1 DH Gipsy Major 10	145	....	90	....	510	520	10,000	2550	1438	36' 4"	23' 6"	.....	113	....	Convertible to ambulance
	Mk. 5	Personal	3	...	1 Lyc	130	....	100	....	770	220	15,000	1820	1088	36'	22' 6.75"	.....	125	....	$2520; mil reconversion
	Mk. 7	Trainer	3	...	1 DH Gipsy Major 7	145	....	107	....	660	350	12,000	2122	1469	36'	23' 9"	6' 6"	122	....	Also observation, communications plane
Blackburn & General Aircraft, Ltd.	G.A.L. 60 Universal Freighter	Transport	4	90	4 Br Hercules 261	1610	2400	176	3250	755	1000	....	100,000	58,599	162'	98'	31'	240	5000	In production
	B.46 Firebrand 5	Strike	1	...	1 Br Centaurus 9	1180	2400	263	10,000	2500	740	28,500	16,317	11,878	51'	39'	15'	350	13,000	Naval fighter-bomber
	Y. A. 5	ASW		...	1 R-R Griffon[7]	...	....	....	....	...	...	....	.....	.....	....	.....	.....	...	....	Anti-sub reconn
Boulton Paul Aircraft, Ltd.	P.108A Balliol T.2	Trainer	2	...	1 R-R Merlin 35	1245	3000	280[8]	10,000	2230	525	32,500	8336	6656	39.33'	35.125'	12.5'	305	11,500	....
Bristol Aeroplane Co., Ltd.	164 Brigand B.1	Bomber	3	...	2 Br Centaurus 57	1970	2400	300	10,000	1455	...	26,300	39,000	26,000	72' 4"	46' 4"	11' 5½"	360	16,300	Light bomber
	167 Brabazon 1	Transport	...	...	8 Br Centaurus 20[9]	1970	2400	...	....	...	...	....	300,000	.....	230'	177'	50'	...	....	One built-research plane only
	167 Brabazon 1B	Transport	...	...	8 Br Proteus 3[9]	3350[13]	....	...	....	...	...	....	.....	.....	230'	178' 10"	50' 8"	...	....	Three ordered
	170 Wayfarer 21E	Transport	3	32	2 Br Hercules 672	1530	2400	162	5000	1090	1420[2]	....	40,000	20,091	108'	68' 4"	21' 6"	224	6500	Also freighter, ambulance types
	175	Transport	...	50-62	4 Br Proteus[10]	...	....	...	....	...	2300	....	....[11]	.....	140'	114'	36' 8.3"	...	....	BOAC ordered 25
Chrislea Aircraft Co., Ltd.	C.H.3 Skyjeep 4	Personal	1	3	1 B1 Cirrus Major 3	145	2200	114	2500	550	520	....	2550	1550	36'	22'	8' 4"	127	2500	Basic price $6300
de Havilland Aircraft Co., Ltd.	D.H.100 Vampire F.6	Fighter	1	...	1 DH Goblin 3	3350[1]	10,750	380	30,000	3700	945	48,500	12,390[12]	7283	38'	30' 9"	6' 2"	548	S. L.	Also supplied to other nations
	D.H.112 Venom	Fighter	1	...	1 DH Ghost	5000[1]	10,000	...	....	...	...	....	.....	.....	41' 9"	31' 5"	.....	...	....	
	D.H. 106 Comet	Transport	4	36-48	4 DH Ghost	5000[1]	10,000	490	36,000	...	...	....	105,000	.....	115'	93'	28' 5"	...	....	Estimated price $1,260,000
	D.H. 104 Dove	Transport	2	8-11	2 DH Gipsy Queen 70-2	345[13]	2800	179	8000	850	600	....	8500	5657	57'	39' 6"	13' 4"	210	8000	Basic price $49,080, 300+ ordered
English Electric Co., Ltd.	Canberra B.L	Bomber	2	...	2 R-R Avon	...	....	...	....	...	...	....	....	.....	64'	65' 6"	15' 6"	...	....	....
Fairey Aviation Co., Ltd.	Advanced Trainer	Trainer	2	...	1 R-R Griffon 12	...	....	...	....	...	...	....	12,000	.....	44' 6"	37' 7"	.....	...	....	Trainer version of Firefly.
	Firefly MK. 5	Fighter	2	...	1 R-R Griffon 74	2250[13]	2750	...	....	...	760	....	13,479	9946	41' 2"	38'	16' 6"	...	..	....
	Fairey 17	Strike	2	...	1 AS Double Mamba	2540[14]	15,000	...	....	...	...	....	....	.....	.....	.....	.....	...	..	Experimental anti-submarine aircraft

Experimental anti-submarine aircraft

Gloster Aircraft Co., Ltd.	Meteor F.4	Fighter	1	...	2 R-R Derwent 5	3500[1]	14,550	555	S. L.	7350	340[15]	44,500	15,175[10]	10,740	37' 2"	41'	13'	585	S. L.	Standard RAF and West Europe fighter
	Meteor F.7	Trainer	2	...	2 R-R Derwent 5	3500[1]	14,550	530	S. L.	7920	520[16]	46,000	14,000	10,290	37' 2"	43' 6"	13'	585	S. L.	Two-seater jet trainer
	Meteor F.8	Fighter	1	...	2 R-R Derwent 5	3500[1]	14,550	...	...	...	...	....	.....	....	37' 2"	44' 7"	13' 10"	..	....	Replaces Meteor 4
Handley Page, Ltd.	Marathon 1	Transport	2	22	4 DH Gipsy Queen 70-2	308	2600	200	5000	683	1030	....	18,000	11,946	65'	52'	14' 1"	233	6750	Order of 40 may be cut back
	Marathon 2	Transport	2	22	2 AS Mamba	1128[17]	15,000	255	10,000	1860	980	....	18,000	10,582	65'	52'	14' 1"	290	20,000	Turbo prop version of Marathon 1
	Hermes 4	Transport	7	40-74	4 Br Hercules 763	1600	2400	283	24,000	1030	3554	....	82,000	54,624	113'	97'	30'	357	20,000	25 ordered
	Hermes 5	Transport	7	40-74	4 Br Theseus	2820[13]	9000	352	20,000	2325	3040	....	90,000	52,887	113'	97'	30'	355	15,000	Tricycle gear
	Hastings	Cargo	5	...	4 Br Hercules 101	1475	2400	302	23,600	890	3886	....	80,000	48,427	113'	81' 8"	22' 6"	347	22,200	3000 cu.ft. cargo cap.
Percival Aircraft, Ltd.	Prince 50	Transport	2	8-12	2 Alvis Leonides 501-4	440	2900	212	10,000	1115	650	....	10,650	7397	56'	42' 10"	16' 1"	225	5000	Feeder line transport
	Prentice 40	Trainer	3	...	1 DH Gipsy Queen 32	250	....	139	1000	655	...	13,600	4000	3232	46'	31' 6"	8'	..	....	RAF basic trainer
Saunders-Roe, Ltd.	Princess SR/45	Transport	8	105	10 Br Proteus[18]	3500[18]	....	380	35,000	...	5500[2]	....	315,000	190,000	219' 6"	148'	55' 9"	..	....	Still under constr.
Short Bros. & Harland, Ltd.	Sealand	Transport	2	5-7	2 DH Gipsy Queen 70	275	2400	173	7750	950	645	....	9100	7319	59'	42' 7"	14'	188	5250	At least 3 ordered by BWIA
	Solent 4	Transport	5	45-80	4 Br Hercules 733	1610	2400	200	10,000	1120	1450	....	79,000	49,000	112' 10"	87' 7"	37' 3"	280	3000	Flying boat
	Sturgeon T.T.2	Target tow	2	...	2 R-R Merlin 140	1440[13]	2850	312	15,000	2470	1152	33,000	22,100	17,647	59' 8"	48' 11"	19'	366	24,200	Royal Navy
	702A Viscount	Transport	4	40-53	4 R-R R.D.a 3	1400	14,500	338	15,000	1700	1740	....	50,000	31,596	94'	81' 17"	26.75'	..	....	Basic price $476,000; about 40 ordered
	Valetta C. 1	Transport	4	36	2 Br Hercules 230	1645	2400	265	10,000	1300	520	....	36,500	25,543	89.25'	65'	19.5'	294	5500	RAF transport; about 200-250 on order
	Varsity	Trainer	..	...	2 Br Hercules	....	....	...	...	...	...	....	37,500	....	95.5'	67.5'	24'	..	....	RAF bomber crew trainer
	Attacker	Fighter	1	...	1 R-R Nene	5000[1]	....	520	30,000	6250	1190	48,500	14,055	7798	36.37'	37'	9.5'	586	S. L.	In production for Royal Navy
	510	Fighter	1	...	1 R-R Nene	5000[1]	....	...	...	...	...	....	....	....	38.64'	38'	8.81'	..	....	Attacker development project
Westland Aircraft, Ltd.	Wyvern T. F. 2	Fighter	1	...	1 AS Python	3670[19]+	8000	...	...	...	...	....	....	....	44'	42'	....	..	....	Royal Navy torpedo plane-fighter
FRANCE																				
S. A. des Ateliers d' Aviations Louis Breguet	763	Transport	4+	130	4 P&W R-2800 CA-18	1800	2600	224	...	...	2367	....	96,000	52,536	140' 10"	94' 11"	31' 4"	248	....	15 on order
	890 H Mercure	Transport	2	...	2 Br Hercules 739	....	....	186	...	...	621	....	39,600	22,330	110' 5"	70' 10"	23' 7"	236	....	
	891R Mars	Transport	5	...	2 SNECMA 14R-200	1282	....	186	...	836	1242	26,500	37,147	25,352	100.4'	71'	23' 7"	261	19,000	Military freighter
	892S Mercure	Transport	3	40	4 Ren 12S 02-201	390	3100	177	4920		621		35,200	19,778	100' 5"	70' 10"	23' 7"	218	8200	
Avions Hurel Dubois	HD 10	Research	1	...	1 Mathis G2F	32	2600	115	SL	400	800	12,000	1150	770	40'	18'	4.2'	135	SL	High aspect ratio wing plus lift struts
Fouga & Co.	CM8. R13 Cyclone	Personal	1	...	1 Turbomeca	176[1]	....	150	SL	790	185	28,000	1182	805.4	42'7.75"	21'10"	5'10"	162	15,000	Glider with gas turbine
	CM 100	......	2	18	2 Ren 12SO2-201	495	3250	158	6000	900[2]	...	....	15,600	11,000	88'	59'	19'	180	7500	....
Aeroplanes Morane Saulnier	MS 700	Personal	4	...	2 Potez D33	160[13]	....	161	3280	945	745	20,340	4885	3620	46' 7"	32' 6"	11' 2"	180	4920	....
SIPA	S11	Trainer	2	...	1 Ren 12S 00	390	3100	205	...	1772	435	27,230	4563	3699	36' 11"	30'7.25"	8'	223	7875	Advanced trainer
	S901	Personal	2	...	1 Minie 4 DC-30	70	2200	110	1000	455	320	12,200	1320	795	27'	18'	5.2'	125	SL	....
S. N. A. C.	N.C. 211 Cormoran	Trainer	4	131	4 GR 14R	1200	....	199	9840	...	1243	....	92,593	59,910	144' 4"	100'	33'1.5"	249	9840	....
	N.C. 702 Martinet	Transport	2	8	2 Ren 12 S 00	495	....	202	9840	...	503	....	12,346	8741	71'7.25"	42'	14'5.5"	217	9840	....
	N.C. 853	Personal	2	...	1 Minie 4DC-32	70	2200	87	...	460	310	7000	1408	801	36' 11"	22' 5"	....	95	....	100 ordered
	N.C. 1071	Torpedo	3	...	2 Hispano – Nene	4600	12,000	476	13,120	4725	...	43,330	25,190	16,258	65' 7"	34' 6"	14' 9"	492	19,680	....
S. N. A. S. E.	S. E. 161 Languedoc	Transport	6	33	4 GR 14 N 68/69	1020	2400	233	7548	591	1678	....	45,364	27,890	96'5"	79' 7"	16' 10"	290	SL	100 ordered
	S. E. 1010	Photo	..	...	4 SNECMA 14R 28/29	1325	2400	248.6	33,000	...	3110	....	72,160	39,000	101.6"	71.54'	21'	323	SL	High-altitude photo survey plane
S. N. C. A. S. O.	S. E. 2010 Armagnac	Transport	6	84	4 P&W R-4360 B-13	2650	2550	296	19,680	...	3600	....	165,000	81,633	160' 7"	129' 10"	44'3.5"	335	19,680	15 ordered
	S.O. 30P Bretagne	Transport	4	36	2 P&W 4-2800 CA-18	1800	2600	273	17,400	...	853	....	42,150	27,350	88' 4"	62'1.5"	19'	304	18,000	45 ordered
	S.O. 95 Corse 2	Transport	2	10-13	2 Ren 12 SO2-201	390	3100	218	8860	...	750	....	12,346	9016	59'	40' 5"	14' 1"	221	S L	60 ordered
	S.O. 6000 Triton	Fighter	2	...	1 Hispano-Nene 109	4600[1]	12,000	594	SL	9840	600[20]	30,000	10,032	7050	32' 8"	34' 2"	....	630	S L	....
	S.O. 6020 Espadon	Fighter	1	...	1 Hispano-Nene 102	4600[1]	12,000	700	30,000	5500	..	36,000	17,640	11,297	34' 9"	48' 2"	....	647	S L	Six 15-mm. guns
	S.O. 7060 Deauville	Personal	3	...	1 Walter Minor 4-111	80	2300	106	3280	...	400	....	1760	1140	34'	21' 11"	7' 11"	127	....	Two prototypes built
	S.O. 8000 Narval	Fighter	1	...	1 Arsenal 12H 02	1740	....	...	...	...	..	21,000	15430	....	38'6.5"	38'8.5"	....	453	25,000	Pusher-engine carrier fighter
	S.O. M2	Research	1	...	1 R-R Derwent 5	3000[1]	14,000	...	...	...	..	....	10,340	8450	29'5.5"	39'5.5"	....	..	....	Flying model of S.O. 4000

* – approximate
AS – Armstrong Siddeley
Bl – Blackburn
Br – Bristol
Con – Continental
DH – de Havilland
GR – Gnome Rhone

Lyc – Lycoming
Mk. – Mark
P&W – Pratt & Whitney
Re – Renault
R-R – Rolls-Royce
SL – sea level
1 – pounds thrust

2 – maximum range
3 – As landplane. Seaplane gross weight is 7540 lb., empty is 4700 lb.
4 – At 280 mph. with maximum payload
5 – Estimated engine shaft hp.
6 – With metal prop.
7 – Fitted to prototype. Production model is designed to use turboprop, probably Armstrong Siddeley Double Mamba
8 – With rich fuel mixture
9 – Four coupled installations
10 – Or 4 Bristol Centaurus 663 piston engines
11 – Payload is 17,610 lb.
12 – With bombs and rockets
13 – Takeoff hp.
14 – Given is shaft hp.; there is also 770 lb. thrust
15 – At 40,000 ft. without drop tanks
16 – Without drop tanks
17 – Engine shaft hp.
18 – Eight in four coupled installations; two as single units
19 – Maximum takeoff shaft hp.
20 – Duration is 1 hr. 30 min.

SPECIFICATIONS OF U.S. TRANSPORT AIRCRAFT

		CAPACITY			POWER PLANT							PERFORMANCE											WEIGHTS		DIMENSIONS			
		Number of crew	Number of passengers	Cargo capacity (cu. ft.)	Number and make of engines	Take off hp.	At rpm. at sea level	Normal rated hp.	At rpm.	At altitude (ft.)	Make of propellers	Diameter (in.)	High speed (mph.)	At altitude (ft.)	Cruising speed, mph.	At altitude (ft.)	Take off distance (ft.) over 50 ft. obstacle	Landing distance (ft.) over 50 ft. obstacle	Landing speed (mph.)	S.L. climb at gross weight (fpm.)	S.L. climb with one engine inoperative (fpm.)	Normal range (mi.)	Gross weight (lb.)	Empty weight (lb.)	Span	Length	Height overall	Direct operating cost per (passenger) (ton) mi.
Beech Aircraft Corp. Wichita, Kan.	D18S	1	8	....	2 P&W R-985-AN14B	450	...	...	....	.....	HS	99	230	5,000	211	10,000	1760	1460	77 [1]	1190	225	908	8,750	5,770	47' 7"	33' 11½"	9' 2½"	....
Boeing Airplane Co. Seattle, Wash.	377 Stratocruiser	3-5	55-80	845	4 P&W R-4360	3500	2700	2650	2550	25,000	C,HS	200	375	25,000	300+	25,000	6250 [2]	....	93	1100	...	4600	142,500	83,500	141' 3"	110' 4"	38' 3"	....
Consolidated Vultee Aircraft Corp. San Diego, Calif.	240 Convair-Liner	3	40	329	2 P&W R-2800-CA18	2400	2800	1800	2600	6,000	HS	157	313	13,500	288	16,000	2250	2000 [3]	108	1420	260	975	41,200	26,100	91' 9"	74' 8"	26' 11"	1.1¢/pas.
Douglas Aircraft Co., Inc. Santa Monica, Calif.	DC-6	5-7	48-58	541	4 P&W R-2800-CA15	2400	2800	1800	2600	6,000	C,HS	157	356	19,600	313	20,400	3720	2150 [3]	91	1070	560	3820	97,200	51,495	117' 6"	100' 7"	28' 5"	.96¢/pas.
	DC-6A-1135	3	None	5000	4 P&W R-2800-CB16	2400	2800	1800	2600	8,500	HS	157	360	18,100	311	20,600	3950	2250 [3]	93	1010	520	3560	100,000	49,767	117' 6"	105' 7"	28' 8"	5.2¢/ton
	Super DC-3-1189A	3	31	282	2 Wr R-1820-C9HE [4]	1475	2800	1275	2500	3,500	HS	138	270	5,900	251	15,400	2510	2490	77	1300	280	1425	31,000	19,537	90'	67' 8½"	18' 3"	.95¢/pas.
	DC-6B-1198	5	52-66	970	4 P&W R-2800-CB16	2400	2800	1800	2600	8,500	HS	157	360	18,100	311	20,600	3950 [5]	2250 [3]	93	1010	520	3560 [6]	100,000	54,148	117' 6"	105' 7"	28' 8"	.97¢/pas.
Glenn L. Martin Co. Baltimore, Md.	2-0-2	3	36	346	2 P&W R-2800-CB16	2400	2800	1800	2600	8,500	HS	157	312	14,500	286	12,000	3740	2320 [3]	86	1790	460	1380	42,750	26,211	93' 3"	71' 4"	28' 5"	....
Grumman Aircraft Engineering Corp. Bethpage, L.I., N.Y.	G-73 Mallard	2	10	....	2 P&W R-1340-53H1	600	2250	550	2200	5,000	HS	103	215	6,000	180	8,000	1920	2340	...	1920	...	730	12,750	9,350	66' 8"	48' 4"	18' 9"	....
Lockheed Aircraft Corp. Burbank, Calif.	749A Constellation	5-7	34-64	434	4 Wr 749C-18BD1	2500	2800	2100	2400	4,400	C,HS	...	354	19,200	300	23,000	3680	1500 [3]	91	1230	640	....	107,000	59,000	123'	95' 3"	23'	....

C - Curtiss Electric
HS - Hamilton Standard

P&W - Pratt & Whitney
Wr - Wright

1 Stalling speed.
2 CAR field length.
3 With reversible props.
4 Also available with P&W R-2000 engines.
5 Based on requirements for CAR 4b.
6 36 passengers and 1000 lb. of cargo.

SPECIFICATIONS OF LEADING HELICOPTERS OF THE U.S.

Manufacturer	Designation	No. of places	POWER PLANT: No. of engines, make and model no.	Takeoff hp.	At rpm.	Fuel cons. cruising (gph)	PERFORMANCE: High speed (mph.)	Cruising speed (mph.)	S. L. climb at gross weight (fpm.)	Hovering ceiling (ft.) without ground effect	Absolute ceiling (ft.)	Normal range (mi.)	WEIGHTS: Gross weight (lb.)	Empty weight (lb.)	Rotor disk loading	Power loading	MAIN ROTOR: No. of rotors	Blades per rotor	Diameter	Total blade area (sq. ft.)	Rotor rpm., cruising	ANTI-TORQUE ROTOR: No. of blades	Diameter	Total blade area (sq. ft.)	Rotor rpm., cruising	No. built
American Helicopter Co., Inc. Manhattan Beach, Cal	XA-5	2	1AHC AJ 8.75 pulse jet	70	...	..	80*	...	...	...	14,000*	...	1500	920	1.75	18.6	1	2	33'	...	...	..	...	...	...	1
Bell Aircraft Corp. Buffalo 5, N. Y.	47D1	3	1 Fr 6V4-178-B32	178	3000	12	92	85	800	8500 [1]	11,000	200	2,200	1380	2.3	12.3	1	2	35' 1.5"	35.24	333	2	5'8"	2.4	1800	18
	48A (YH-12B)	5-8	1 P&W R-1340-55	600	2250	25	105	90	...	...	15,000	300	6,286	4450	3.4	10.5	1	2	47.5'	70.96	279	2	8.5'	5.25	1406	11
	54 (XH-15)	2	1 [2]	275	3200	..	...	...	...	...	...	...	2,700	2000	2.5	10.6	1	2	...	...	332	2	6.45'	...	1800	3
Doman Helicopters, Inc. Danbury, Conn.	Pelican	...	1 Airc 6AL-500	245	3000	14.2	85	75	1135	3300	14,000	225	3,200	1800	2	13.1	1	4	45'	686	210	3	8'	4.7	1360	... [3]
Gyrodyne Co. of America New York, N. Y.	2	5	1 P&W Wasp Jr. B-4	450	2300	27	112	89	1250	7000	22,100	270	5,400	3600	2.98	12	2	2	48'	1810	192	..	...	...	...	1
	5	3	1 Con XO-470-5	274	3200	19	161	155	1200	14700	21,000	264	2,795	2035	2.75	10.2	1	4	36'	1017	312	2	7'	38.5	2350	1 [5]
	7 [4]	12	2 Ly GSO-580	375	3300	60	162	150	760	8800	23,000	250	7,600	4646	3.59	10.1	2	2	52'	2120	230	..	...	...	...	1
Kaman Aircraft Corp. Windsor Locks, Conn.	K-225 (XHK-225) [6]	3	1 Ly 0-435	225	3000	13	73	65	1000	4000	12,000	200	2,500	1800	1.97	11.1	2	2	38'	...	236	..	...	...	...	7
Kellett Aircraft Corp. Camden 11, N. J.	KH-2X (XH-10)	12	2 Con R-975-15	525	2450	46	120+	90	1650	6000	20,000+	350	11,000	8256	2.97	10.5	2	3	65'	296	140	..	...	...	...	1
McDonnell Aircraft Corp. St. Louis, Mo.	Whirlaway (XHJD-1)	10	2 P&W R-985	450	...	..	110	90	1300 [7]	...	...	350	11,000	...	3	12.3	2	3	50' [8]	330	...	..	...	...	...	1
	Little Henry	1-2	2 McD ramjets	...	...	..	50+	...	...	...	...	...	630+	280	...	...	1	2	18'	...	640	..	...	...	...	2
Penn Elastic Co. Phila., Pa.	B 1	2	1 Fr 335	150	2575	9*	...	...	...	...	...	...	1,300	700	2.97	13.3	2	3	29.5'	26.26	320	..	...	...	...	1
Piasecki Helicopter Corp. Morton, Pa.	PV-3 (HRP-1)	10	1 P&W R-1340	600	...	30	120	85	800	4500	12,000	300	6,900 [9]	5000	...	...	2	3	41'	...	...	..	...	...	...	20
	PV-14 (HUP-1)	5	1 Con R-975-34	525	2300	24	130	110	1600	8000	16,500	400	5,355 [10]	3966	...	...	2	3	35'	...	...	..	...	...	...	3 [11]
	(HRP-2)	10	1 P&W R-1340-AN-1	600	...	30	105	85	800	4500+	11,000	300	6,978 [12]	5054	...	...	2	3	41'	...	...	..	...	...	...	...
	PV-15 (XH-16)	...	...	...	...	..	...	...	...	...	...	...	...	...	...	...	..	..	...	...	...	..	...	...	...	...
Siebel Helicopter Co., Inc. Wichita, Kan.	S-4	2	1 Ly 0-235-CI	115	2800	7	70	65	800	10,000	15,000	200	1,450	930	2.2	12.6	1	2	29'	22	390	2	5.5'	...	1525	1
Sikorsky Aircraft Div., United Aircraft Corp. Bridgeport, Conn.	S-51(H-5 or HO3S-1)	4	1 P&W R-984-B-4	450	2300	28	103	85	1000	5,000	14,600	255	5,500	3805	2.92	11.2	1	3	49'	87.6	194	2	8'8"	6.16	1278	100**
	S-52-2 (H-18A)	3-4	1 Fr 6V6-245-B16F	245	3275	14	118	92	1050	2,800	12,500	415	2,600	1650	3.04	10.6	1	3	33'	...	...	2	5'4"	...	...	1
	S-55 (H-19)	12	1 P&W R-1340	600	2250	35	110	86	1100	3,600	14,600	470	6,800	4200	3.08	11.3	1	3	53'	...	194	2	8'8"	...	1360	1
United Helicopters, Inc. Palo Alto, Calif.	360	3	1 Fr 6V4-178-B-33	178	3000	12	84	76	625	...	9,000	200	2,247	1447	2.34	12.6	1	2	35'	32.3	327	2	5.5'	...	1895	35

AHC - American Helicopter Co.
Fr - Franklin
P&W - Pratt & Whitney
Airc - Aircooled Motors
Ly - Lycoming

Con - Continental
McD - McDonnell
** Approximate 1949 output. * Approximate.
1 In ground effect.
2 1 Continental XO-470-9 or Franklin XO-425-7 engine.

3 Prototype under construction.
4 Convertible aircraft; coaxial rotor plus stub wing.
5 Being built.
6 U. S. Navy type.
7 With one engine, climb at sea level is 200 fpm.

8 9 ft. intermesh.
9 Overload gross weight is 8000 lb.
10 Overload gross weight is 5605 lb.
11 22 on order.
12 Overload gross weight is 7267 lb.

SPECIFICATIONS OF U.S. RECIPROCATING ENGINES

Manufacturer	Model	Cooling System	Number of Cylinders	Cylinder Arrangement	Propeller Drive	RATING				WEIGHTS		Bore and stroke (in.)	Displacement (cu. in.)	Compression Ratio	B. M. E. P.	Blower	DIMENSIONS			Guaranteed Fuel Consumption at Cruising Hp. (Lb. per hp. per hr.)	Maximum Oil Consumption at rated speed	Cylinder Construction	Make spark plugs supplied with engine	Make Ignition	Make of Carburetors	Make of Starter
						Rated Hp.	At R.P.M.	At Altitude (ft.)	Octane Fuel	Total dry without hub or starter	Lb. per hp.						Diam. Mount Ring or distance between bearers (in.)	Ht. or O. D. (in.)	Length without starter (in.)							
Aircooled Motors, Inc.	4A4-90-B3	A	4	ho	D	90	2300	SL	80	230[1]	2.56	4.5x3.5	225	7	138	. . .	31.21	27.59	30.68[4]	.50	.015	ai	Ch	Ei	MS	Au
Syracuse 8, N. Y.	4A4-100-B3	A	4	ho	D	100	2550	SL	80	230	2.30	4.5x3.5	225	7	138	. . .	31.21	27.59	30.68	.50	.015	ai	Ch	Ei	MS	Au
	6A4-150-B3	A	6	ho	D	150	2600	SL	80	321[1]	2.14	4.5x3.5	335	7	136	. . .	31.21	22.59	37.37[4]	.50	.015	ai	Ch	Ei	MS	DR
	6A4-165-B3	A	6	ho	D	165	2800	SL	80	324[1]	1.97	4.5x3.5	335	7	140	. . .	31.21	25.21	37.37[4]	.50	.015	ai	Ch	Ei	MS	DR
	6V4-178-B32[2]	A	6	vo	D	178	3000	SL	80	308[1]	1.73	4.5x3.5	335	7	140	. . .	30.81	38.18	30.75	.52	.015	ai	Ch	Sc	MS	DR
	6V4-165-B32F[2]	A[3]	6	vo	D	165	3000	SL	80	356[1]	2.16	4.5x3.5	335	7	138	. . .	30.81	42.50	30	.55	.015	ai	Ch	Sc	Be,MS	DR
	6V4-200-C32[2]	A	6	vo	D	200	3100	SL	91	333	1.66	4.5x3.5	335	8.5	152	. . .	31.12	38.18	29.03	.52	.015	ai	Au	Sc	Be,MS	DR
	6AG4-185-B12	A	6	ho	G.632:1	185	3100	SL	80	369	1.80	4.5x3.5	335	7.5	145	. . .	31.15	26.12	40.59[4]	.51	.015	ai	Ch	Sc	Be,MS	DR
	6V6-245-B16F[2]	A[3]	6	vo	D	245	3275	SL	80	353	1.44	4.7x4	425	7.5	140	. . .	33.28	38	39.21	.52	.015	ai	AC	Ei	Be	. . . . .
	6A8-215-B8F	A[3]	6	ho	D	215	2500	SL	80	487	2.26	5x4.2	500	7	136	. . .	33.90	29.25	66	.55	.015	ai	Au	Ei,Sc	MS	Au
Continental Motors Corp.	A65-8	A	4	ho	D	65	2300	. . . .	73	176	2.7	3.8x3.6	171	6.3	. . . .	. . .	. . . .	. . . .	31[5]	.49	.010	. . .	Au	Ei,JIC	Str	. . . . .
Muskegon 82, Mich.	C75-12	A	4	ho	D	75	2275	. . . .	73	184	2.42	4x3.6	188	6.3	. . . .	. . .	. . . .	. . . .	32[5]	.52	.010	. . .	Au	Sc	Str	DR
	C85-8F	A	4	ho	D	85	2575	. . . .	73	176	2.07	4x3.6	188	6.3	. . . .	. . .	. . . .	. . . .	31[5]	.51	.010	. . .	Au	Sc	Str	. . . . .
	C85-12	A	4	ho	D	85	2575	. . . .	73	184	2.14	4x3.6	188	6.3	. . . .	. . .	. . . .	. . . .	32[5]	.51	.010	. . .	Au	Sc	Str	DR
	C90-8F	A	4	ho	D	90	2475	. . . .	80	184	2.07	4x3.8	201	7	. . . .	. . .	. . . .	. . . .	31[5]	.52	.010	. . .	Au	Sc	Str	DR
	C90-12F	A	4	ho	D	90	2475	. . . .	80/87	188	2.06	4x3.8	201	7	. . . .	. . .	. . . .	. . . .	32[5]	.52	.010	. . .	Au	Sc	Str	DR
	C125-2	A	6	ho	D	125	2550	. . . .	73	256.8	2.05	4x3.6	282	6.3	. . . .	. . .	. . . .	. . . .	41[5]	.50	.017	. . .	Ch	Sc	MS	DR
	C145-2	A	6	ho	D	145	2700	. . . .	80/87	265	1.82	4x3.8	301	7	. . . .	. . .	. . . .	. . . .	41[5]	.50	.017	. . .	Ch	Sc	MS	DR
	E165	A	6	ho	D	165	2050	. . . .	80/87	344	2.08	5x4	471	7	. . . .	. . .	. . . .	. . . .	46.66[5]	.51	.017	. . .	BG	Sc	Str	DR
	E185	A	6	ho	D	185	2300	. . . .	80/87	344	1.86	5x4	471	7	. . . .	. . .	. . . .	. . . .	46.66[5]	.50	.020	. . .	BG	Sc	Str	DR
	GE240-1	A	6	ho	G.69:1	240	2900	. . . .	80/87	394	1.60	5x4	471	7	. . . .	. . .	. . . .	. . . .	52.03[5]	.53	.020	. . .	BG	Sc	Str	Ec
	W670-23	A	7	rad	D	240	2200	. . . .	80/87	519	2.12	5.1x4.6	667.8	6	. . . .	. . .	. . . .	. . . .	35.56[5]	.52	.025	. . .	Ch	Sc	Str	. . . . .
	R-9A	A	9	rad	D	500	2300	. . . .	91	705	1.34	5x5.5	972	6.3	. . . .	. . .	. . . .	. . . .	42.5[5]	.46	.025	. . .	Ch	Sc	Str	. . . . .
Jacobs Aircraft Engine Co	0-240A	A	4	ho	D	100	2300	SL	80	200	2.04	4.37x4	241	6.5	143	. . .	16	18.1	39.6	.50	.015	als	Op	Dr,Ei	MS	Dr
Pottstown, Pa.	0-360A	A	6	ho	D	165	2400	SL	80	300	1.82	4.37x4	361	6.5	151	. . .	16	18.1	47.4	.50	.015	als	Op	Dr,Ei	MS	Dr
	R-755A	A	7	rad	D	300	2200	SL	80	505	1.68	5.25x5	757	6	143	. . .	16.5	44	39.5	.45	.015	als	Ch	Sc	Str	Ec
	R-755E	A	7	rad	G3:2	350	2500	SL	91	600	1.72	5.25x5	757	6.5	146	. . .	16.5	44	42.3	.46	.025	als	Ch	Sc	Str	Ec
	R-915A	A	7	rad	D	375	2300	SL	80	560	1.49	5.5x5.5	914	6	141	. . .	16.5	45.6	40.4	.50	.015	als	Ch	Sc	Str	Ec
Lycoming-Spencer Div. AVCO Mfg. Corp.	0-145-B2	A	4	ho	D	65	2550	SL	73	163.4	2.54	3.6x3.5	145	6.5	140	. . .	. . . .	20.59	24.62	.51	. . .	ai	Ch	Sc	MS	. . . . .
Williamsport, Pa.	0-235-CI	A	4	ho	D	108	2600	SL	80	235[6]	2.26	4.3x3.8	233	6.75	141	. . .	. . . .	22.53	29.56[6]	.52	. . .	aiS	Ch	Sc	MS	DR
	0-290-D	A	4	ho	D	125	2600	SL	80	258[6]	2.06	4.8x3.8	289	6.5	132	. . .	. . . .	22.81	29.56[6]	.52	. . .	aiS	Ch	Sc	MS	DR
	GO-290-A	A	4	ho	G77:120	160	3000	SL	91/98	376[6]	2.35	4.8x3.8	289	7.5	146	. . .	. . . .	28.5	34.59[6]	.49	. . .	aiS	Ch	Sc	MS	DR
	0-435-A	A	6	ho	D	190	2550	SL	80	392[6]	2.32	4.8x3.8	434	6.5	136	. . .	. . . .	29.59	38.10[6]	.52	. . .	aiS	Ch	Sc	MS	DR
	0-435-A2	A	6	ho	D	225	3000	SL	91/98	392[6]	1.93	4.8x3.8	434	7.5	137	. . .	. . . .	29.59	38.10[6]	.51	. . .	aiS	Ch	Sc	MS	DR
	GO-435-A2	A	6	ho	G77:120	240	3000	SL	91/98	460[6]	1.91	4.8x3.8	434	7.3	146	. . .	. . . .	29.59	40.71[6]	.47	. . .	aiS	Ch	Sc	MS	DR
	GO-435-C2	A	6	ho	G77:120	240	3000	SL	91/98	432	1.80	4.8x3.8	434	7.3	146	. . .	. . . .	29.59	39.57[6]	.47	. . .	aiS	Ch	Sc	MS	. . . . .
	GSO-580	A	8	ho	G77:120	320	3000	SL	91/98	619	1.67	4.8x3.8	578	7.3	146	7.91	. . . .	19.97	57.58[6]	.50	. . .	aiS	Au	Sc	Be	. . . . .
	GSO-580-B	A	8	ho	G77:120	350	3000	SL	100/130	624	1.78	4.8x3.8	578	7.3	160	7.91	. . . .	19.97	57.58	.50	. . .	aiS	Au	Sc	Be	. . . . .

Manufacturer	Model	Cooling System	Number of Cylinders	Cylinder Arrangement	Propeller Drive	RATING: Rated Hp.	RATING: At R. P. M.	RATING: At Altitude (ft.)	RATING: Octane Fuel	WEIGHTS: Total dry without hub or starter	WEIGHTS: Lb. per hp.	Bore and stroke (in.)	Displacement (cu. in.)	Compression Ratio	B. M. E. P.	Blower	DIMENSIONS: Diam. Mount Ring or distance between bearers (in.)	DIMENSIONS: Ht. or O. D. (in.)	DIMENSIONS: Length without starter (in.)	Guaranteed Fuel Consumption at Cruising Hp. (Lb. per hp. per hr.)	Maximum Oil Consumption at rated speed	Cylinder Construction	Make spark plugs supplied with engine	Make Ignition	Make of Carburetors	Make of Starter
McCulloch Motors Corp. Los Angeles, Calif.	4318	A	4	ho	D	Pend.	Pend.	SL	95	83	Pend.	3.18x3.12	99.8	7.8	Pend.	....	8.12	15	27	Pend.	...	al	Ch	Own	Own	Manual
	4300	A	4	ho	D	60	4000	SL	95	83	1.38	3.x3.12	88.4	7.8	66.3	....	8.12	15	27	.85	...	ai	Ch	Own	Own	Manual
Pratt & Whitney Div. United Aircraft Corp. E. Hartford, Conn.	Wasp Jr. B5[7]	A	9	Rad	D	450	2300	2300	91/98	682[6]	1.54	5.18x5.18	985	6	157	10[13]	....	46.10	42.43	....	...	als	Op	Sc	Be	.....
	Wasp S1H1[8]	A	9	Rad	D	550	2200	8000	91/98	865[6]	1.57	5.75x5.75	1344	6	148	12	....	51.80	43.01	....	...	als	Op	Sc	Be	.....
	Wasp S3H1-G[9]	A	9	Rad	G.667:1	550	2200	5000	91/98	865[6]	1.57	5.75x5.75	1344	6	148	12	....	51.80	47.81	....	...	als	Op	Sc	Be	.....
	Twin Wasp S1C3-G	A	14	RadS	G.5625:1	1050	2550	7500	91/98	1467[6]	1.4	5.5x5.5	1830	6.7	.178	7.15	....	48.19	61.16	....	...	als	Op	Sc	Be	.....
	Twin Wasp D5	A	14	RadS	G2:1	1200	2550	6400	100/130	1575[6]	1.3	5.75x5.5	2004	6.5	187	7.15	....	49.10	61.02	....	...	als	Op	Sc	Be	.....
	Twin Wasp 2SD13-G	A	14	RadS	G2:1	1200	2550	5000	100/130	1595[6]	1.3	5.75x5.5	2004	6.5	187	7.15[13]	....	49.10	61.02	....	...	als	Op	Sc	Be	.....
	Twin Wasp E1	A	14	RadS	G.4375:1	1300	2600	8000	100/130	1870[6]	1.5	5.75x6	2180	6.7	182	7	....	54	75.80	....	...	als	Op	Sc	Be	.....
	Double Wasp CA3[10]	A	18	RadS	G.450:1	1800	2600	6000	100/130	2317[6]	1.3	5.75x6	2804	6.75	196	7.15	....	52.80	78.40	....	...	als	Op	Sc	Be	.....
	Double Wasp CA17[11]	A	18	RadS	G.450:1	1800	2600	6500	115/145	2350[6]	1.3	5.75x6	2804	6.75	196	7.29[13]	....	52.80	78.40	....	...	als	Op	Sc	Be	.....
	Double Wasp CB1	A	18	RadS	G.450:1	1900	2600	7000	115/145	2357[6]	1.3	5.75x6	2804	6.75	205	7.29	....	52.80	81.40	....	...	als	Op	Sc	Be	.....
	Double Wasp CB12[12]	A	18	RadS	G.4375:1	1800	2600	8500	100/130	2390[6]	1.3	5.75x6	2804	6.75	196	7.29[13]	....	52.80	81.40	....	...	als	Op	Sc	Be	.....
	Double Wasp CB16	A	18	RadS	.....	1800	2600	8500	100/130	2390	...	5.75x6	2804	6.75	...	8.4	....	....	81.40	....	.025	als	Op	Sc	Be	.....
	Wasp Major TSB3-G	A	28	RadS	G.357:1	2650	2550	5500	115/145	3482[6]	1.3	5.75x6	4363	7	188	6.375	....	54	96.75	....	...	als	Op	Sc	Be	.....
	Wasp Major B13	A	28	RadS	G.425:1	2650	2500	6000	115/145	3520[6]	1.3	5.75x6	4363	7	188	6.95[14]	....	54	101	....	...	als	Op	Sc	Be	.....
Ranger Aircraft Div. Fairchild E & A Corp. Farmingdale, L. I., N. Y.	6-440C-2	A	6	id	D	175	2450	SL	65	382	2.18	4.12x5.5	441	6	128	....	17.875	33.5	53.16	.49	...	S	BG	Sc	Be	.....
	6-440C-5	A	6	id	D	200	2450	SL	87	382	1.91	4.12x5.5	441	7.5	146	....	17.875	33.5	53.16	.44	...	S	BG	Sc	Be	.....
	SGV-770C-1B	A	12	id	G	450	3000	12,000	91	759	1.46	4x5.12	773	6.5	169	9.5	13.375	34.13	66.45	.49	...	S	AC	Sc	Be	.....
	SGV-770C-2A	A	12	id	G	500	3150	9000	100	757	1.37	4x5.12	773	6.5	171	8.84	13.375	34.13	66.45	.59	...	S	BG	Sc	Be	.....
	SGV-770D-1	A	12	id	G	565	3300	8000	100	855	1.38	4x5.12	773	6.5	181	7.04	13.375	31.11	74.95	.54	...	S	BG	Sc	Be	.....
	SGV-770D-4	A	12	id	G	465	3200	13,500	100	896	1.56	4x5.12	773	6.5	173	10.12	13.375	36.75	77.24	.54	...	S	BG	Sc	Be	.....
Wright Aeronautical Corp. Wood-Ridge, N. J.	R-1300-1	A	7	Rad	G16:9	700	2400	5000	91	1045	1.28	6.125x6.3125	1300	6.2	188	7.21[18]	....	50.45	48.12	.46	.015	Als	Op	Bo	Be	Op
	R-1820-101A	A	9	Rad	G16:9	1275	2500	3000	100	1400	.98	6.125x6.875	1820	6.8	238	7.21[18]	....	54.95	48.5	.45	.015	Als	Op	Be	Be	Op
	959C9HE1	A	9	Rad	G16:7	1475	2500	2500	122/145	1398	.91	6.125x6.875	1820	6.8	242	7.21[18]	....	54.95	48.5	.45	.015	Als	Op	Bo	Be	Op
	745C18BA3[15]	A	18	Rad	G16:7	2000	2400	4800	100	2780	1.2	6.125x6.3125	3350	6.5	187	6.46[18]	....	55.78	76.26	.46	.020	Als	Op	Be	Be	Op
	749C18BD1[15]	A	18	Rad	G16:7	2100	2400	4400	100	2884	1.03	6.125x6.3125	3350	6.5	238	6.46[18]	....	55.62	78.52	.48	.020	Als	Op	Be	Be	Op
	R-3350-26W[16]	A	18	Rad	G16:7	2300	2600	....	115/145	2848	1.06	6.125x6.3125	3350	6.5	221	6.46[18]	....	55.62	81.93	.44	.020	Als	Op	Bo	Be	Op
	R-3350-30W[17]	A	18	Rad	G16:7	3250	2900	....	.....	...	...	6.125x6.3125	3350	...	...	.....	....	56.25	91.80	....	....	Als	Op	Be	Be	Op

ai – aluminum and cast iron
als – aluminum and steel
Au – Autolite
Be – Bendix
Bo – Bosch
BG – BG Corp.
Ch – Champion
D – direct drive
Dr – Delco Remy
Ec – Eclipse Ei – Eisemann
G – geared
ho – horizontally opposed
id – inverted
MS – Marvel Schebler
Op – Optional
Rad – radial
RadS – Staggered radial
S – steel
Sc – Scintilla
Str – Stromberg
vo – vertically opposed

1 – Weight includes starter, generator, other parts and accessories.
2 – For helicopter installation.
3 – Cooling fan installed.
4 – Length includes starter.
5 – Length overall.
6 – Includes starter and other accessories.
7 – Wasp Jr.B4 has same performance but is designed for use with crankshaft in vertical plane.
8 – Wasp S1H1-G has same performance but has .667 prop reduction gear and dry weight is 953 lb.
9 – Wasp S3H1 has same performance but has direct drive and 865 lb. dry weight. S3H2 has same performance, same dry weight, is direct drive, and is designed for operation with crankshaft in vertical plane.
10 – CA5 has additional 200 hp. at takeoff.
11 – Similar engines are models CA15, CA18 and CA19.
12 – CB13 has 1900 normal rated hp. at 2600 rpm. at 7000 ft.
13 – Low impeller gear ratios. High ratios are: 9.52 for 2SD13-G; 9.10 for CA17.
14 – High impeller ratio is shown.
15 – Direct fuel injection.
16 – Impeller injection.
17 – Compound engine.
18 – Low impeller ratios. High ratios are: 8.69 for R-1300-1; 10.14 for R-1820-101A; 8.69 for 959C9HE1; 8.67 for 745C18BA3; 8.67 for 749C18BD1; 867 for R-3350-26W.

SPECIFICATIONS OF CANADIAN, BRITISH, AND FRENCH JET ENGINES

Manufacturer	Model	Type	Compressor stages	Turbine stages	Compression ratio	Static thrust (lb.)	At rpm.	Rated thrust (lb.)	At rpm.	At altitude (ft.)	Maximum overspeed (rpm.)	Shaft hp.	At rpm. (S. L.)	Specific fuel cons., (lb./lb. thrust/hr.)	Turbine inlet (F deg.)	Tailpipe (F deg.)	Length (in.)	Diameter (in.)	Weight, dry (lb.)
CANADA																			
A. V. Roe Canada, Ltd.	Orenda	TJ	11AF[1]	..	....	7000 +[1]	.....	.....	.....	....	.....	....	.....	.....	....	....	135[1]	42[1]	......
	Chinook	TJ	9AF	1	4.5:1	2600	10,100	.....	.....	....	.....	....	.....	1.04	1112	1202	125	32	1250
ENGLAND																			
Bristol Aeroplane Co., Ltd.	Proteus	TP	13AF	3	....	800	10,000	.....	.....	....	.....	3200	10,000	.63[2]	....	....	113.3	38.5	3050
	Coupled Proteus	TP	13AF	3	....	1600	10,000	.....	.....	....	.....	6400	10,000	.63[2]	....	....	167.3	80.4	7180
	Theseus 502	TP	9AF	3	4.25:1	825	8200	145[3]	7800	20,000	.....	2220	8200	.773[2]	1470	1020	82.6	54	2205
de Havilland Engine Co., Ltd.	Goblin 35	TP	1CF	1	....	3500	10,750	2950[3]	10,250	S. L.	11,075	....	.....	1.13[3]	....	1274	108.5	50	1619
	Ghost	TJ	1CF	1	....	5000	10,250	4300[3]	9750	S. L.	10,550	....	.....	1.04[3]	....	1292	121	53	2174
Rolls-Royce, Ltd.	Avon R. A. 2	TJ	AF	..	....	6000	.....	.....	.....	....	.....	....	.....	1.00	....	....	125	41.5	2450*
	Tay	TJ	1CF	1	....	6250[5]	.....	.....	.....	....	.....	....	.....	.....	....	....	103.2[4]	50	2000*
	Nene	TJ	1CF	1	4:1	5000[5]	12,300	.....	.....	....	.....	....	.....	1.00	1526	1166	96.8	49.5	1550[6]
	Derwent 5	TJ	1CF	1	4:1	3500[5]	14,700	.....	.....	....	.....	....	.....	1.00	1526	1166	83.1	43	1250[6]
	Dart	TP	2CF	2	5.5:1	.....	.....	.....	.....	....	.....	1400	14,500	.83	1526	1004	95.18	38.5	929
FRANCE																			
Hispano – Suiza	Nene 102	TJ	1CF	1	4:1	5000	12,300	4600	12,000	S. L.	.....	....	.....	1.065	1607	1292	96.8	49.5	1550
Rateau	SRA 101	TJ	10AF	2	6.8:1	8800	9500	.....	.....	....	.....	....	.....	1.88	1742	1202	121[7]	43	2200

* – approximate
TJ – turbojet
TP – turboprop

AF – axial flow
CF – centifugal flow
1 – Aviation Week estimate

2 – at lb./hr./ehp.
3 – maximum continuous thrust
4 – without after burner

5 – type test rating
6 – includes accessories
7 – without tailpipe

SPECIFICATIONS OF U.S. GAS TURBINE ENGINES

Manufacturer	Model	Type	Compressor stages	Turbine stages	Compression ratio	Static thrust, lb.	At rpm. at sea level	Rated thrust at SL	At rpm.	Shaft hp.	At srpm. at sea level	Spec. fuel cons. lb./hr./lb. thrust or shp.	Turbine inlet, F. deg.	Tailpipe, F. deg.	Overall length, in.	Overall diameter, in.	Dry weight, lb.	Gross weight, lb.
Allison Division General Motors Corp. Indianapolis, Ind.	400 (J-33-A-23)[1]	C	1	1	4.4:1	5400[2]	11,750	3900	11,250	....	....	1.12[3]	....	1290	107[4]	50.5	....	1795
	450 (J-35-A-17)[5]	A	11	1	5:1	5000	7800	4240	7400	....	....	1.05[3]		1185	146[7]	37	....	2260[8]
	500 (XT 40)[6]	TP	17	4	6.3:1	....	.....	.....	.....	5500	....	.63		....	84[7]	25x39	....	2500[8]
	501 (XT 38)	TP	17	4	6.3:1	....	.....	.....	.....	2750	....	.63		....	84[7]	20	....	1225[8]
American Helicopter Co., Inc. Manhattan Beach, Calif.	AJ 8.75	PJ	...	...	....	95	.....	.....	.....	....	....	2.5	....	....	40	8.75	20	.....
Boeing Airplane Co. Seattle, Wash.	500	C	1	1	3:1	190[9]	38,000	165[10]	36,000	....	....	1.22	1500	1250	29[11]	22	....	111
	502	TP	1	2	3:1	....	.....	.....	.....	200[12]	2700	1.2	1500	1150	42	22	....	184
Frederic Flader, Inc. N. Tonawanda, N. Y.	-124 (J-55-FF-1)	A	...	1	....	770	28,200	700	26,800			1.64	....	1170	79	15.75	....	300
General Electric Co. Aircraft Gas Turbine Div. West Lynn, Mass.	TG-190 (J-47)	A	12	1	....	5200[13]	.....	.....	.....	....	....	....	....	....	144	36.75	....	2500*
Pratt & Whitney Aircraft Div. United Aircraft Corp. East Hartford, Conn.	JT 6B (J-42)[15]	C	1	1	....	5000[14]	.....	4000	.....	....	....	109	....	....	103.2[17]	49.5	....	1723
	JT 7 (J-48)	C	1	1	....	6250[16]	.....	.....	.....	....	....	....	....	....	103.2	50	....	2000*
Westinghouse Electric Corp. Aviation Gas Turbine Div. Philadelphia, Pa.	24C4B (J-34-WE-22)	A	11	2	....	3000	.....	2290	.....	....	....	....	....	....	120	24	....	1200

* - approximate
A - axial flow
C - centrifugal flow
PJ - pulsejet
srpm - shaft rpm.
TP - turboprop

1 - Present allowable time between overhauls for this engine is 300 hr. Navy designation is J-33-A-10, engine is similar except for accessory housing. A later model has afterburner.
2 - Using water/alcohol injection.
3 - At cruising.
4 - With tail cone.
5 - Present allowable time between overhauls is 300 hr.
6 - Two T-38 power sections joined to form one unit connected to reduction gear by extension shafts. Each unit can operate the 6-bladed Aeroproducts contra-rotating props independently or together.
7 - Plus extension shafts and reduction gear.
8 - Includes shafting and reduction gear.
9 - Takeoff static rating.
10 - Continuous static rating.
11 - Without tail cone.
12 - Takeoff static rating. Continuous static rating is 160 shp. at 2450 srpm.
13 - Without augmentation - more with water injection.
14 - Thrust rating wet is 5750 lb.
14 - Thrust rating wet is 5750 lb.
15 - Powers Grumman F9F-5, Lockheed F-94B and North American F-93A.
16 - Approximately 8000 lb. thrust with afterburner.
17 - Without afterburner.

U.S. PROPELLER MANUFACTURERS AND THEIR PRODUCTS

Manufacturer	Classification	Pitch Actuation	Hp. Range	Blade Data: Price Range	Blade Data: Number	Blade Data: Diameter (in.)	Construct.	Military Planes Using
Aeromatic Propeller Dept. Koppers Co., Inc. Baltimore, Md.	GA, CP, CR, AV	Hyd,[1] Mech[1]	50-500	$400	2-4	72-108	Wd[2]	OY-1
Aeroproducts Division General Motors Corp. Dayton, Ohio	CP, CS, RP, FF, CR, AV	Hyd	500-3000+	$5000-$25,000+	2-8	99-216	St[3]	C-45, T-28, F-82, F8F, AD-2, 4, P4M, XP5Y
Beech Aircraft Corp. Wichita, Kan.	CS, FF	Elec	240-300	....	2	88-96[4]	Wo[5], AL	Beech T-34
Curtiss-Wright Corp. Propeller Division Caldwell, N. J.	CP, CS, RP, FF, CR, AV, SR, SFP	Elec, Elec Mech	1000-3000+	....	3-8	120-252	St[6]	AM-1, B-29, B-36, B-50, C-74, C-97, C-99, C-118, C-121, C-122, JRM-1, 2, PBM-5, 5A, R-12, R60-1, C-124, C-125, ZPN airship.
Flottorp Mfg. Co. Grand Rapids, Mich.	FP, GA, CP	Hyd, Mech	50-200	$50-$400	2	63-102	Wd[7]	L-13
G. B. Lewis Co. Watertown, Wisc.	FP	....	50-200	$50-$100	2	68-76	Wd[8]	None
Hamilton Standard Propeller Division United Aircraft Corp. E. Hartford, Conn.	TP, CP, CS, RP, FF	Hyd	200-3000+	....	2-4	96-198	AL[9] St[10]	R4Q, AM-1, AJ, P4M, P2V,, AF-2W, AF-2S, F4U-5, C-119, C-97, XC-120, C-82, XC-123, C-125, T-31, T-29, SA-16, YC-124A
Hartzell Propeller Co. Piqua, Ohio	GA, TP, CP, CS, RP, CR	Hyd	50-500	$50-$400	2-3	68-102	AL, Pl[11]	L-5, L-17 UF
McCauley Corp. Dayton, Ohio	FP	....	50-200	$125-$200	2	58-90	AL[12]	L-16A, L-16B, YL-15
Sensenich Corp. Lancaster, Pa.	FP, GA, TP, CP, CS	Hyd	50-200	$50-$400	2-4	60-102	Wd,[13] Me	....
U. S. Propellers, Inc. Pasadena, Calif.	FP, GA, CP, AV[14]	Mech[14]	50-1000	$50-$400	2-8	10-150	Wd,[15] AL[16]	....

Al-aluminum alloy
Av-automatically variable
Cp-controllable pitch
AL-aluminum alloy
AV-automatically variable
CP-controllable pitch
CR-counter-rotating
CS-constant speed
Elec-electric
Elec Mech-electric mechanical
FF-full feathering

FP-fixed pitch
GA-ground adjustable
Hyd-hydraulic
Me-metal
Mech-mechanical
RP-reversible pitch
SFP-selective fixed pitch
SR-single rotating
St-steel
TP-two position
Wo-wood

1-Models F200H and 220H are hydraulically actuated, model 220-1 is mechanically actuated.
2-Laminated maple or birch with plastic covering and metal tipping.
3-Hollow steel incorporating reinforcing rib.
4-91-in. model is constant speed experimental type.
5-Wood, plastic covered, flush tipping.
6-Two machined preformed sheets welded together to form hollow monocoque.
7-Laminated birch, plastic covered.
8-Laminated birch
9-Solid aluminum alloy ground from forging.
10-Airfoil envelope with central spar for core; air spaces are filled with vulcanized sponge rubber.
11-Solid plastic construction Hartzite composition with stainless steel tipping.
12-Drop forged heat treated.
13-Controllable models are made from laminated wood blank, plastic covered, metal tipping.
14-Made to specifications only.
15-Laminated birch.
16-Aluminum and plastic, plastic covered.

SPECIFICATIONS OF U.S. HIGH SPEED RESEARCH AIRPLANES

Manufacturer	Designation	Engine	Span	Length	Height	Gross Weight	Max. Design Speed
Bell................	X-1	Reaction Motors rocket 6000 lb. thrust pressure fuel system	28′	31′	10′ 10″	13,069	1000 mph. @ 60,000 ft.
Bell................	X-1A	Reaction Motors rocket 6000 lb. thrust turbine fuel system	28′	31′	10′ 10″	13,400	1700 mph. @ 80,000 ft.
Bell................	X-2	Curtiss Propeller rocket	Swept wing, stainless steel				2250 mph. @ 100,000 ft.
Douglas.............	X-3	Various	Design studies only				2500 mph. @ 200,000 ft.
Northrop...........	X-4	(2) Westinghouse 19XB2B 1600 lb. thrust ea.	25′	20′	15′	7,000	650 mph. @ 10,000 ft.
Douglas............	D-558-I	G E Allison J-35 4000 lb. thrust	25′	25′	12′	10,000	650 mph. @ seal level
Douglas............	D-558-II	Westinghouse 24C, 3000 lb. and Reaction Motors rocket 6000 lb. thrust	25′	45′ 3″	11′ 6″	16,000	1820 mph. @ 75,000 ft.

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